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1830 NASA Road 1, Houston, Texas 77058
Tel. 713-333-5411

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TECHNICAL MEMORANDUM

LACIE PHASE III DIRECT WHEAT STUDY OF NORTH DAKOTA

By

M. C. Kinsler, J. D. Nichols, and A. L. Oña

Approved By: Luis M Flores
L. M. Flores, Supervisor
Design Integration Section

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J. G. Vineyard

D. T. Register

C. W. Haynes

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ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS:

AA	Accuracy Assessment (Section)
AI	analyst interpretation
APU	agrophysical unit
BCE	bias-corrected estimate
CAMS	Classification and Mensuration Subsystem
CAS	Crop Assessment Subsystem
CRD	crop-reporting district
JSC	Johnson Space Center
LACIE	Large Area Crop Inventory Experiment
Landsat	Land Satellite
PFC	production film converter
pixel	picture element
USDA	U.S. Department of Agriculture
YES	Yield Estimation Subsystem

SYMBOLS:

A	oats
B	barley
F	flax
GT	ground truth
M	machine-classified
N	nonsmall grains
O	oats
OSG	other small grains
P_W	proportion of spring wheat
P_w	percentage of spring wheat
R	rye
S	machine-classified small grain
S_{BCE}	bias-corrected estimate for spring small grains
SG	spring grains
W	wheat
WW	winter wheat

1. INTRODUCTION

1.1 BACKGROUND

In Phases I, II, and III of the Large Area Crop Inventory Experiment (LACIE), Classification and Mensuration Subsystem (CAMS) analysts generated acreage estimates of all small grains and confusion crops that were spectrally similar to small grains when viewed on imagery acquired by the Land Satellite (Landsat). Sample segment acreage estimates were sent to the Crop Assessment Subsystem (CAS) for aggregation. Confusion crop ratios were applied to determine wheat acreage estimates.[1]

A LACIE objective was to estimate a segment's wheat proportion using Landsat imagery and thus to reduce the dependence on historical ratios. A direct wheat procedure, developed utilizing LACIE Phase II North Dakota blind site ground-truth data, was implemented during LACIE Phase III North Dakota operations. A spring wheat estimate separate from other spring small grains was determined and passed to CAS for all processable LACIE Phase III North Dakota segments.

1.2 OBJECTIVES

This paper, a documentation of the LACIE Phase III direct wheat procedure and the subsequent study of the separation of spring small grains, accomplishes the following objectives:

1. Explanation of the LACIE Phase III direct wheat procedure.
2. Statistical evaluation and analysis of the procedure.
3. Summary of the effectiveness of the procedure.
4. Establishment of spring small grain separation parameters.
5. Establishment of an optimal crop calendar development stage for separation.
6. Improvement and refinement of separation procedures.

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[1] An explanation of the types of ratios used in LACIE Phases I, II, and III is given in "The Crop Assessment Subsystem – System Implementation and Approaches Used for the Generation of Crop Production Reports" by W. E. McAllum et al., to be published.

2. DATA SET

2.1 LACIE PHASE III BLIND SITES IN NORTH DAKOTA

The blind sites represent a random sample drawn from the operational segment data base at a one-third ratio arrayed by the number of LACIE segments in the state, crop reporting district (CRD), and county. Aerial color-infrared photographs (scale of 1:24 000) processed by personnel at the Johnson Space Center (JSC), ground-truth field data surveyed by the county executive director of the Agricultural Stabilization and Conservation Service of the U.S. Department of Agriculture (USDA), ground-truth field overlays for the color-infrared photographs, and a universal-format ground-truth file registered to the Landsat imagery are available for the majority of the blind sites.

The 18 of 27 North Dakota blind sites selected for study and evaluation met the following criteria:

1. The blind sites were located in North Dakota.
2. Aerial color-infrared photographs were available.
3. Landsat data were acquired.
4. Field ground-truth survey was available.
5. Segment received a satisfactory CAMS acreage estimate. (See reference 9 for explanation of a satisfactory estimate.)
6. Each site contained less than 500 fields.

The blind site segments and the corresponding county, CRD, agrophysical unit (APU), and Analyst Interpretation (AI) Keys' partition comprising the data set are listed in table 1; and their locations are shown on the North Dakota map (fig. 1).

2.2 DESCRIPTION OF NORTH DAKOTA

North Dakota, the heart of the northern Great Plains spring wheat region, has fertile soils and dominantly smooth topography favorable for agriculture. The variety of crops that can be cultivated is limited by the low annual rainfall and the short growing season. Dryland spring wheat production dominates the

TABLE 1.– NORTH DAKOTA BLIND SITE SEGMENT INFORMATION

Segment number	County	CDR	APU	AI keys partition	Acquisition dates (1977, Julian date[a])/adjusted Robertson scale[b]								
					Pre-planting	Planting	Emergence	Jointing	Heading	Soft dough	Ripe	Harvest	Harvest
1602	Mountrail	1	21	27		7125/1.9	7143/2.7		7179/4.3	7198/5.4			
1604	Ranville	1	19	29		7125/1.9	7143/2.7						
1606	Ward	1	19	29		7125/1.9	7143/2.7		7179/4.3	7197/5.3			7250/>6.0
1616	Cavalier	3	20	25		[c]7122/1.6	7141/2.7	[c]7158/3.5				7230/>6.0	
1619	Grand Forks	3	20	24		7122/1.6	7140/2.7	7158/3.5	7175/4.3			7230/>6.0	
1622	Ramsey	3	19	25		7122/1.6	[b]7140/2.6	[c]7158/3.5	7176/4.3			7230/>6.0	
1625	Dunn	4	21	26		7125/2.1			7179/4.4	7197/5.2		7233/>6.0	
1635	Sheridan	5	19	29	7105/<1.0			7159/3.6					
1637	Stutsman	5	21	25			7140/2.6			7194/5.3			7248/>6.0
1640	Barnes	6	19	24		[c]7121/1.5	7140/2.6		7175/4.4	7193/5.4	7211/>6.0	7229/>6.0	
1648	Bowman	7	21	26	7107/<1.0	7125/2.0	7143/2.9		7179/4.5				
1652	Stark	7	21	26		7125/1.9	7143/2.8		7179/4.2	7197/5.0		7233/>6.0	
1661	McIntosh	9	21	26		7123/1.8		7159/3.5					
1663	Richland	9	20	24		[c]7120/1.2	[c]7138/2.4	[c]7156/3.5	[c]7174/4.3	7193/5.3	7211/>6.0	7229/>6.0	
1899	Walsh	3	20	24		7122/1.6	7140/2.7	7157/3.5	7175/4.3	7193/5.3			
1903	Mercer	4	21	26		7125/2.2			7179/4.4	7197/5.2		7233/>6.0	
1913	Hettinger	7	21	26		7125/2.2	7143/2.8	7161/3.7	7179/4.6	7197/5.2	7215/>6.0	7233/>6.0	
1927	Sargent	9	19	21		[b]7121/1.8	7140/2.8	[b]7157/3.6	[b]7175/4.4	7193/5.4		7230/>6.0	

[a]Appendix A provides a Julian date calendar (perpetual and for leap years).

[b]S. K. Woolley, personnal communication, Dec. 1977.

[c]First day of consecutive-day coverage.

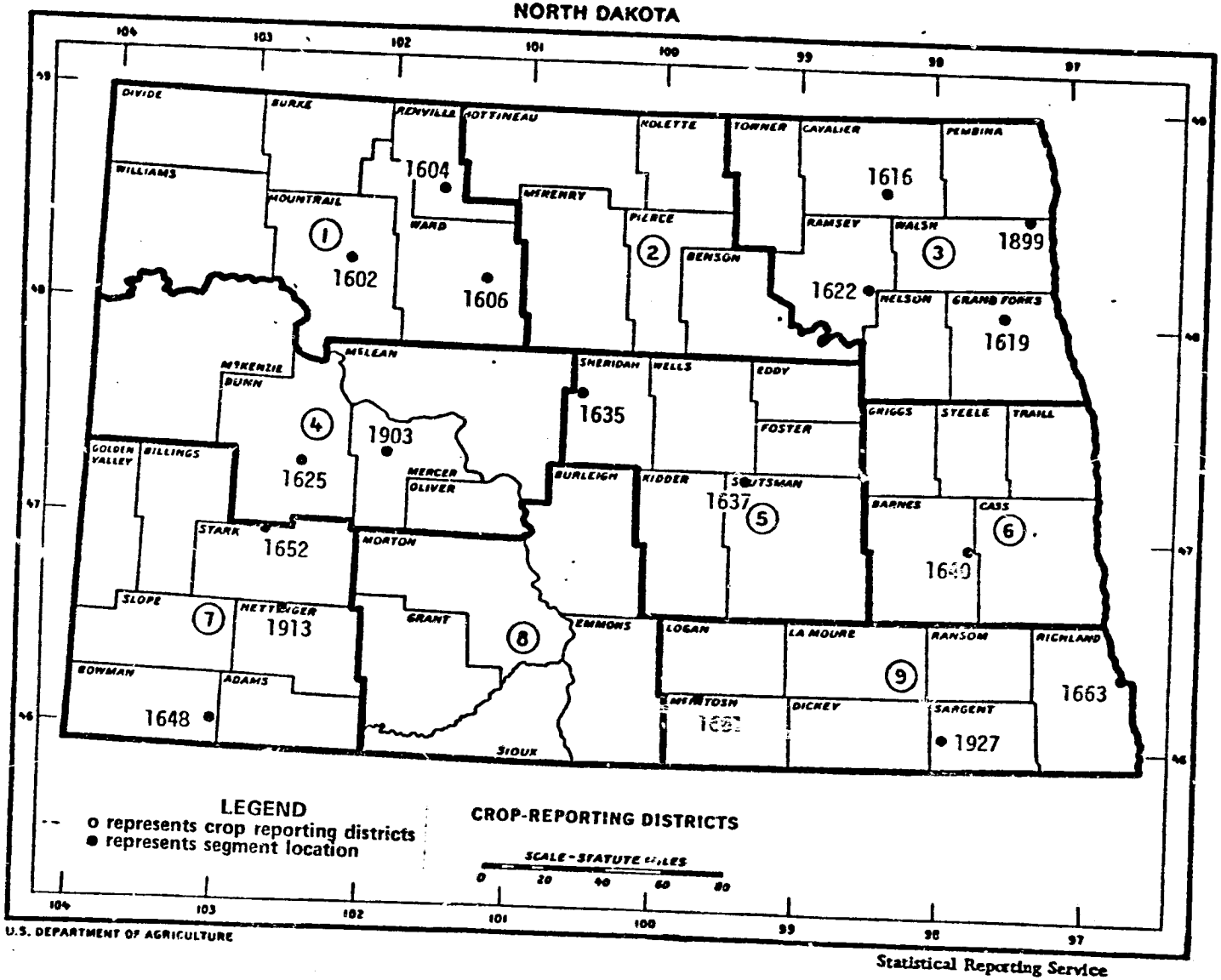


Figure 1.— Locations of North Dakota blind sites.

agriculture of the region. Figure 2 (ref. 1) shows the geographic regions of North Dakota as described in section 2.2.1, and figure 3 (ref. 2) gives the mean annual precipitation. Section 2.2.2 describes the soils of the region, and section 2.3 discusses agricultural practices in the state.

2.2.1 GEOGRAPHIC REGIONS

2.2.1.1 Dark Brown Glaciated Plain

Area 1, a dark brown glaciated plain, is used primarily as farmland and ranchland, with slightly more than half of the acreage devoted to cropland. Spring wheat (the most important crop), feed grains, forage crops, and some flax are grown in the area. Native grasses grow on the more sloping land. Water conservation farming methods are practiced as irrigated cropland is confined to a narrow strip along the Missouri River.

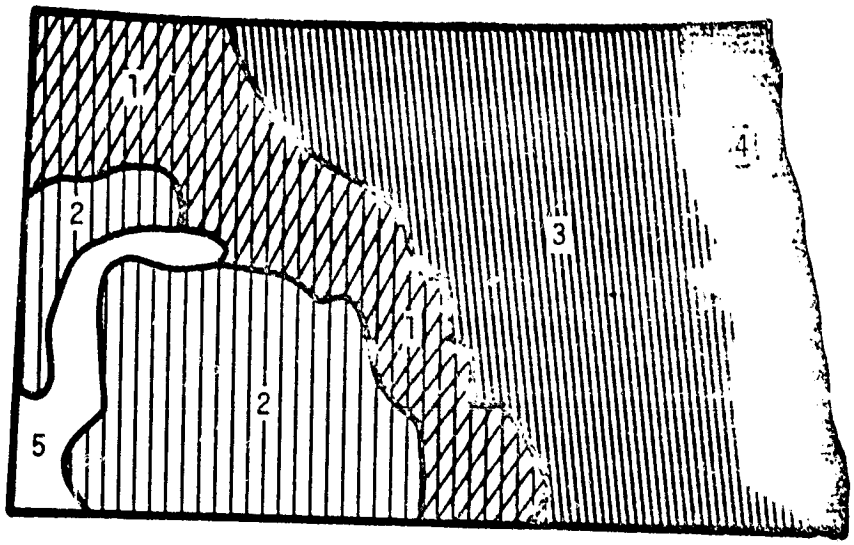
Increasing in elevation from the southeast to the northwest, this gently rolling glaciated plain includes some areas of kames and moraines. The major valleys are bordered by steep slopes and badlands.

The average annual precipitation is 38 to 46 centimeters (15 to 18 inches), with the majority of the rain falling during the growing season. The average freeze-free period is 104 to 140 days.

2.2.1.2 Rolling Soft Shale Plain

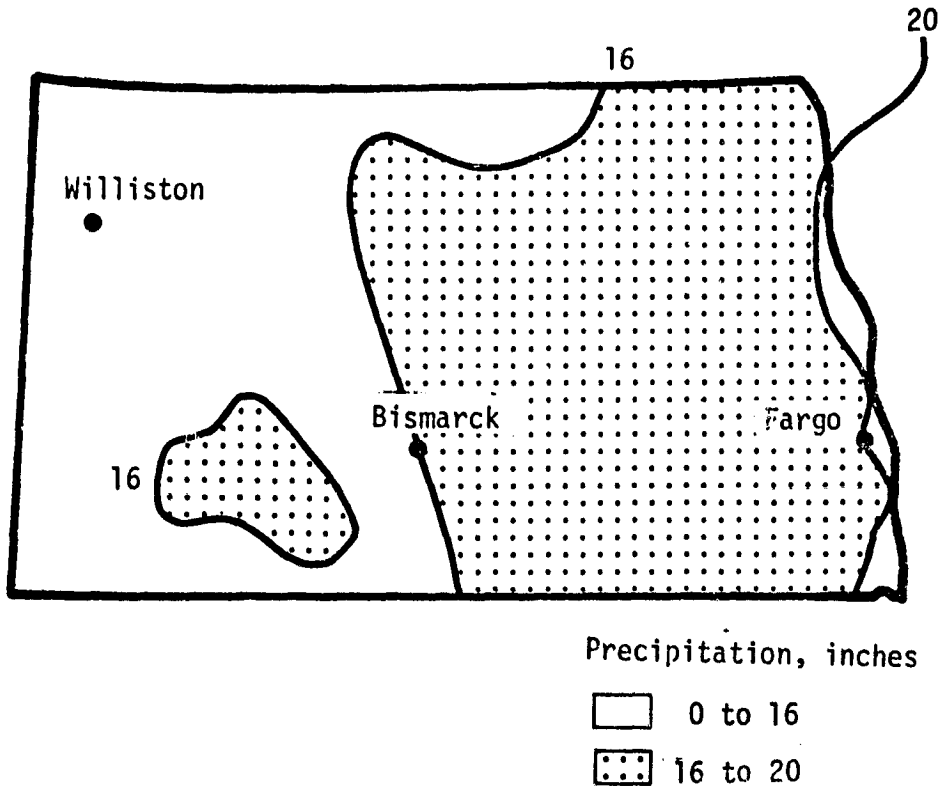
The agriculture of area 2, a rolling soft-shale plain, is a combination of cash grain farming and livestock production. The more gently sloping land is dry-farmed. Rangeland, about three-fifths of the area, is in native grasses and shrubs. Narrow strips along the Missouri River and its tributaries are irrigated. The major crops in this area are wheat, feed grains, hay, and pasture.

The area is a moderately dissected rolling plain predominantly underlain by calcareous shales and sandstones. In some places, the major stream valleys are bordered by strongly dissected areas of sharp local relief, steep slopes,



1 — Dark Brown Glaciated Plain
2 — Rolling Soft Shale Plain
3 — Black Glaciated Plain
4 — Red River Valley
5 — Northern Rolling High Plains

Figure 2.— Geographic regions of North Dakota.
(From ref. 1.)



ure 3.— Mean annual precipitation in North Dakota, 1931 to 1960.
(From ref. 2.)

or badland topography. The northern and eastern fringes have been glacially modified. Farmers use moisture-conserving cultivation methods.

The average annual precipitation, increasing from west to east, is 33 to 48 centimeters (13 to 19 inches). The spring to midsummer months are the wettest. The average freeze-free period is 110 to 135 days.

2.2.1.3 Black Glaciated Plain

Area 3, a black glaciated plain, is used primarily as farmland and ranchland. Three-fourths of the land is devoted to cropland. Wheat is the principal crop, but other small grains, feed grains, hay, and flax are also cultivated. Native grasses grow on the more sloping, thinner soils. Narrow strips of wet soils on the flood plains are wooded. Agriculture is dependent on the erratic precipitation because little irrigation is practiced.

This area is a nearly level glacial plain bordered by rolling morainic hills along its western edge. Local relief is low throughout most of the area.

The average annual precipitation of 36 to 51 centimeters (14 to 20 inches) fluctuates widely from year to year. Late spring to early autumn months are typically the wettest times of year. The average freeze-free period, increasing from north to south, is 100 to 145 days.

2.2.1.4 Red River Valley

In area 4, the Red River Valley, farms and ranches occupy most of the terrain. The poorer soils in the northeast, covering 10 percent of the area, are wooded. Three-fourths of the area is cropland. Spring wheat, potatoes, sugar beets, and corn are the most important crops in area 4. Feed grains and forage for dairy cattle are also principal crops. The more sloping land on the west is rangeland. Normally, there is sufficient moisture for crops, but wide fluctuations from year to year create supply uncertainties. Drainage systems are required in many of the flatter sections. Water management is a problem in this area.

This area is a nearly level glacial lake plain decreasing in elevation from south to north.

Most of the average annual precipitation of 48 to 56 centimeters (19 to 22 inches) falls between late spring and early autumn. The average freeze-free period is 105 to 135 days.

2.2.1.5 Northern Rolling High Plains

Most of area 5, the northern rolling high plains, is ranchland with a very small percentage planted to dry-farmed wheat. Native shrubs and grasses prevail on the rangeland. Rainfall is the principal source of moisture for agriculture; therefore, the limited water supplies must be well managed.

The area is a dissected plain with slopes ranging from rolling to steep.

The average annual precipitation of 30 to 41 centimeters (12 to 16 inches) fluctuates widely from year to year, with most of the precipitation occurring in the spring and early autumn.

2.2.2 SOILS

Eastern North Dakota is dominated by Udic Borolls soils that are moister than average for Borolls, whereas Typic Borolls with average moisture occupy the western portion of the state. Borolls soils have mean annual soil temperatures of less than 47° F (8° C). The eastern soils are nearly black in color and fine loamy to clayey in texture; western soils are dark brown to nearly black in color and loamy to clayey in texture (ref. 3). The soils of North Dakota are mapped in figure 4 (ref. 4).

2.3 AGRICULTURAL PRACTICES

Limited precipitation as well as widely fluctuating annual precipitation controls the cropping practices of the state. Dryland farming of small grains prevails; irrigation is confined mainly to narrow bands along rivers and streams. Generally, the cropping practices can be discussed in two

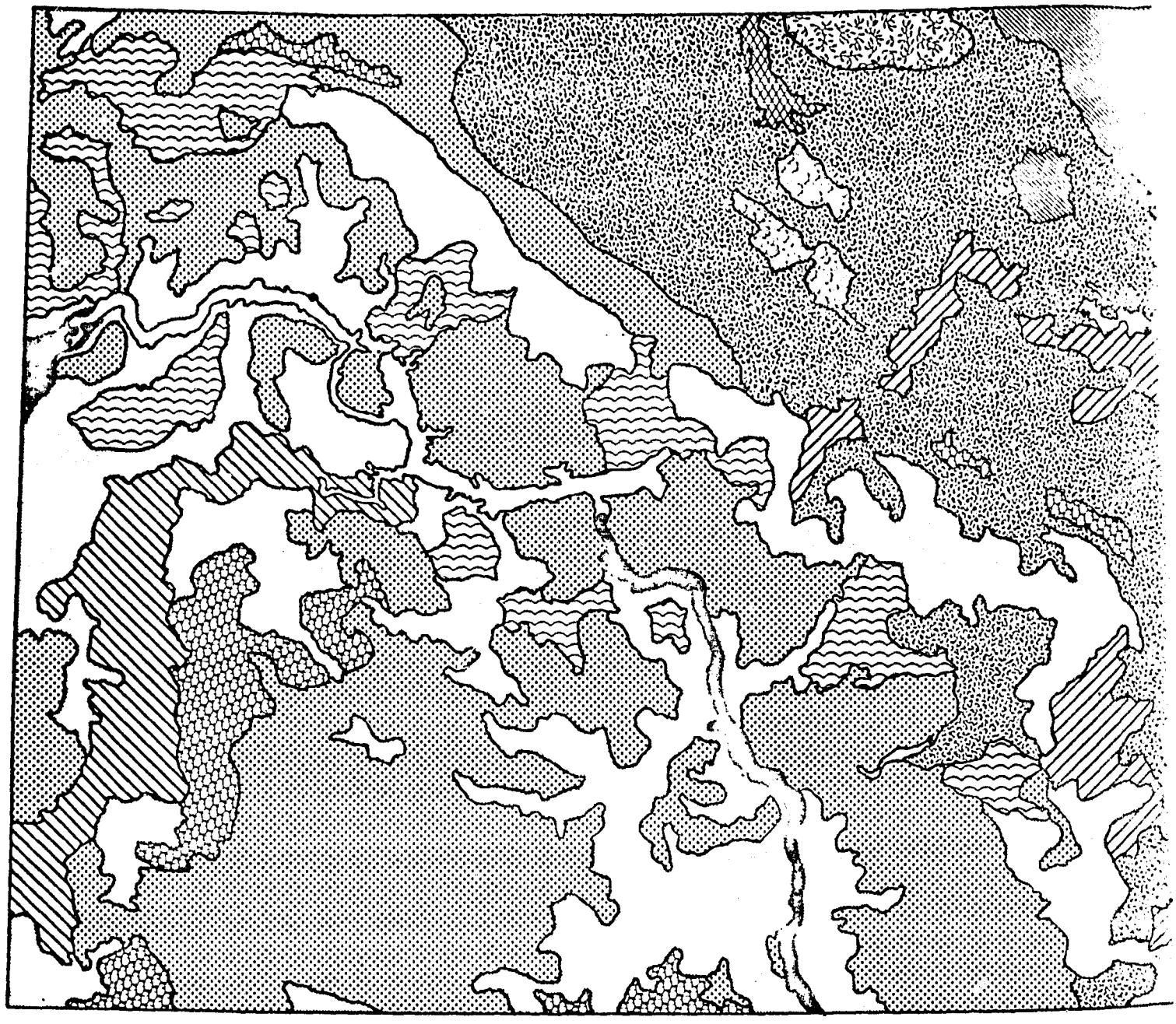
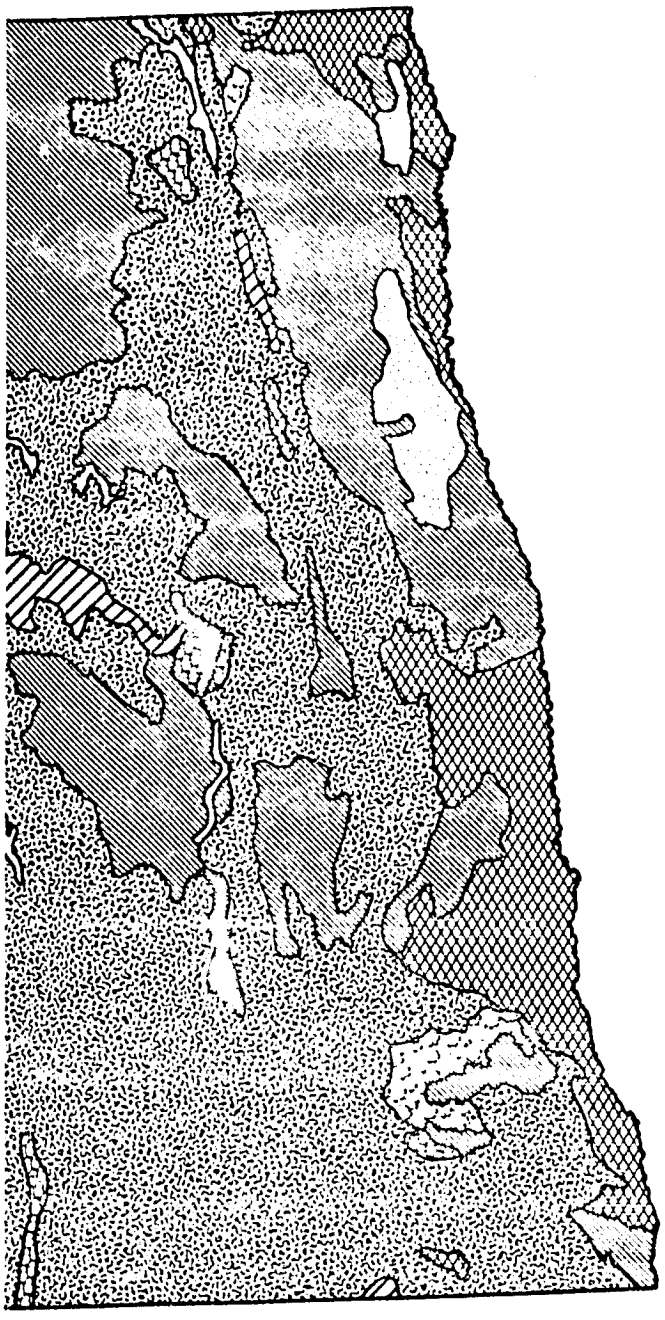


Figure 4.— Soils of



BLACK SOILS OF SUBHUMID GRASSLAND

Nearly level to gently rolling soils with thick black surface layer (Chernozem) and associated soils with very limy subsoil (calcium carbonate Solonchak), with claypan subsoil (Solonetz), or with wet soils (humic gley and planosol): loams and clay loams, sandy loams and loams with sandy substrata, and sandy loams and loams with sandy and gravelly substrata

Rolling soils with thick black surface layer (Chernozem) and associated steeply sloping soils with thin surface layer (regosol): loams

DARK BROWN SOILS OF SEMIARID GRASSLAND

Nearly level to gently rolling soils with thick dark brown surface layer (Chestnut) and associated soils with claypan subsoil (Solonetz) or steeply sloping soils with thin surface layer (regosol and lithosol): loams and clay loams, sandy loams and loams, and sandy loams and loams with sandy and gravelly substrata

Rolling soils with thick dark brown surface layer (Chestnut) and associated steeply sloping soils with thin surface layer (regosol): loams

SOILS OF SUBHUMID WOODLAND

Undulating to rolling soils with gray surface layer (gray wooded) and associated soils with thick black surface layer (Chernozem): clay loams and clays

CLAY SOILS OF GLACIAL LAKE PLAINS

Nearly level soils with thick black surface layer (grumusol)

VERY LIMY SOILS OF SUBHUMID GRASSLAND

Nearly level to undulating soils with very limy subsoil (calcium carbonate Solonchak) and associated soils with thick black surface layer (Chernozem), wet soils (planosol), or saline soils (Solonchak): loams, clay loams, and sandy loams

Saline clay loams and loams

ALKALI SOILS

Nearly level alkali soils with claypan subsoil (Solonetz) and associated nonalkali soils with thick surface layer (Chestnut and Chernozem): loams and clay loams

SOILS OF STREAM VALLEYS

Nearly level soils on bottomlands (alluvial), gently sloping soils on alluvial pans (alluvial and Chernozem), and steeply sloping soils (regosols): loams, sandy loams, and clay loams

SOILS ON STEEP SLOPES

Hilly and steeply sloping soils with thin surface layer (regosol and lithosol) and associated soils with thick surface layer (Chernozem and Chestnut) or with claypan subsoil (Solonetz): rough broken land

Hilly and steep land

SOILS OF SAND HILLS

Hilly, hummocky, and nearly level sandy soils (regosol) and associated wet soils (humic gley): sands and loamy sands

WATER

Body of water

ORIGINAL PAGE IS OF POOR QUALITY

Dakota. (From ref. 4.)

sections: those practices typical of eastern North Dakota and those typical of western North Dakota.

Generally, small grain yields of eastern North Dakota are higher than those of the western part of the state. This trend is a result of the greater precipitation and more fertile soil in the east than in the west. Fields are planted in block dimensions and occasionally in strips. Crop rotation (e.g., a spring small grain grown for 3 to 5 years followed by a year of fallow or by the planting of another crop) is common. Historical land-use patterns affect current cropping practices.

Fields of western North Dakota are planted in combination of strip and block dimensions although strip fields predominate. Spring small grains are planted on summer fallowed land because continuous cropping leads to low-yield situations, thus increasing the risk of crop failure. Approximately half of the area is rangeland of native grasses and shrubs. Seeding and improving native range are common practices in the western portion of the state (ref. 1).

Table 2 illustrates the extent of summer fallowing in North Dakota from 1975 to 1977; the percentage of fallowed land increases from east to west and from south to north. As indicated in the table, fallowed barley acreage was nearly half that of the spring wheats (refs. 5 and 6).

Table 3 lists the percentage of cropland by county and the percentage of cropland planted to spring small grains in 1974 for the blind site counties (ref. 7). This table shows that small grains represent a significant portion of the agricultural area of the blind site counties.

TABLE 2.— EXTENT OF SUMMER FALLOWING IN NORTH DAKOTA

[Expressed in percentages for CRDs 1 through 9]

1975	1976	1977
Hard red spring wheat		
90 71 47 72 54 33 87 47 21 Statewide. . 54	87 64 41 70 48 28 83 39 17 Statewide. . 49	85 70 42 69 51 24 82 51 23 Statewide. . 52
Durum wheat		
85 56 67 88 46 22 85 41 26 Statewide. . 67	80 63 60 85 45 19 81 41 18 Statewide. . 62	84 69 67 87 45 23 87 50 30 Statewide. . 70
Barley		
42 37 28 47 21 13 67 41 9 Statewide. . 25	48 32 23 58 21 14 65 30 9 Statewide. . 23	50 30 19 58 17 6 65 28 11 Statewide. . 20

TABLE 3.— 1974 CROPLAND STATISTICS FOR NORTH DAKOTA BLIND SITE COUNTIES

[From ref. 7]

County	Land in county devoted to crops, %	Cropland planted to spring small grains, %
Barnes	84	59
Bowman	48	42
Cavalier	80	63
Dunn	35	40
Grand Forks	83	56
Hettinger	83	46
McIntosh	67	45
Mercer	46	44
Mountrail	61	44
Ramsey	82	52
Renville	77	54
Richland	82	46
Sargent	76	44
Sheridan	59	50
Stark	64	42
Stutsman	67	58
Walsh	85	60
Ward	73	50

3. DIRECT WHEAT PROCEDURE (INITIAL STUDY)

3.1 DESCRIPTION

3.1.1 SEPARATION GUIDELINES

General separation guidelines, based on established agronomic practices and crop development patterns, were used in assisting the analysts' decisions on separating wheat from other small grains. Although the spectral reflectance patterns of all small grains are similar, the following general differences can be noted:

- Barley is generally planted after wheat.
- Barley tends to green up sooner than spring wheat and tends to obtain higher levels.
- Barley turns and matures earlier than wheat.
- Barley tends to be brighter than wheat after heading.
- Rye is greener than wheat.
- Oats are not as green as wheat and may mature earlier than wheat.

Figure 5 is a sample plot of small grains' green number growth patterns that was intended to provide general guidance in separation decisions. The data on the plot were derived from nine LACIE Phase II North Dakota blind sites.

A field was assumed to be spring wheat unless it could be shown that the field was nonwheat small grains. Figure 6 gives the flexible decision logic that was followed in determining wheat/small grains separation.

3.1.2 PROCEDURE FOR SEPARATING WHEAT FROM OTHER SMALL GRAINS

Listed below is the procedure followed by the analysts in separating wheat from other small grains during LACIE Phase III operations.

1. Evaluated the bias-corrected estimate (BCE) for small grains to determine whether it was satisfactory. The separation procedure was not applied to the segments with an unsatisfactory BCE.
2. Studied the 1975 county grain production maps given in figure 7 (ref. 8) to gain an understanding of the relative importance and ranking of each

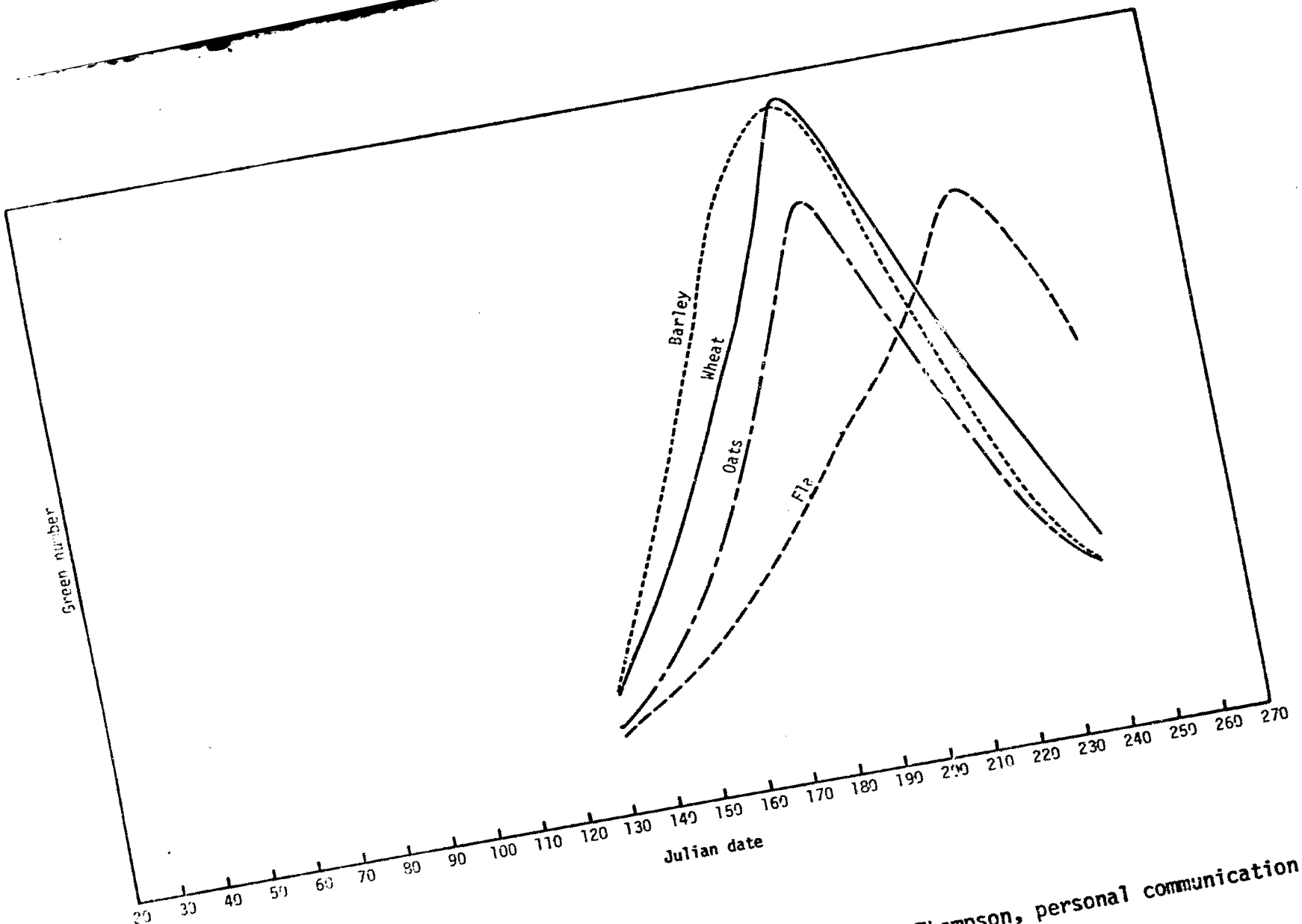


Figure 5.— Green number growth pattern for small grains. (D. R. Thompson, personal communication.)

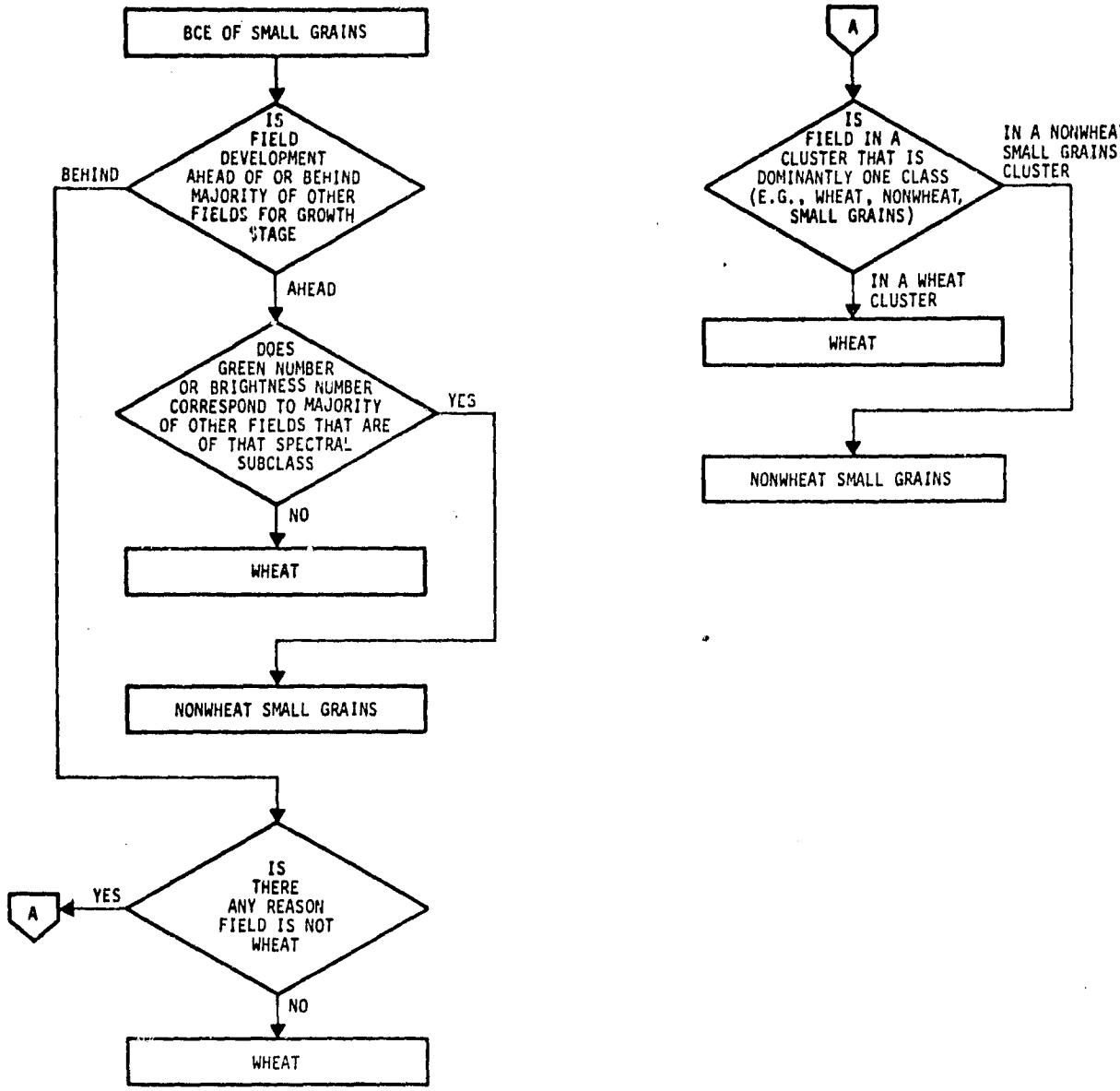


Figure 6.— Decision logic for separating wheat from other small grains. (D. R. Thompson and J. D. O'Connell, personal communication.)

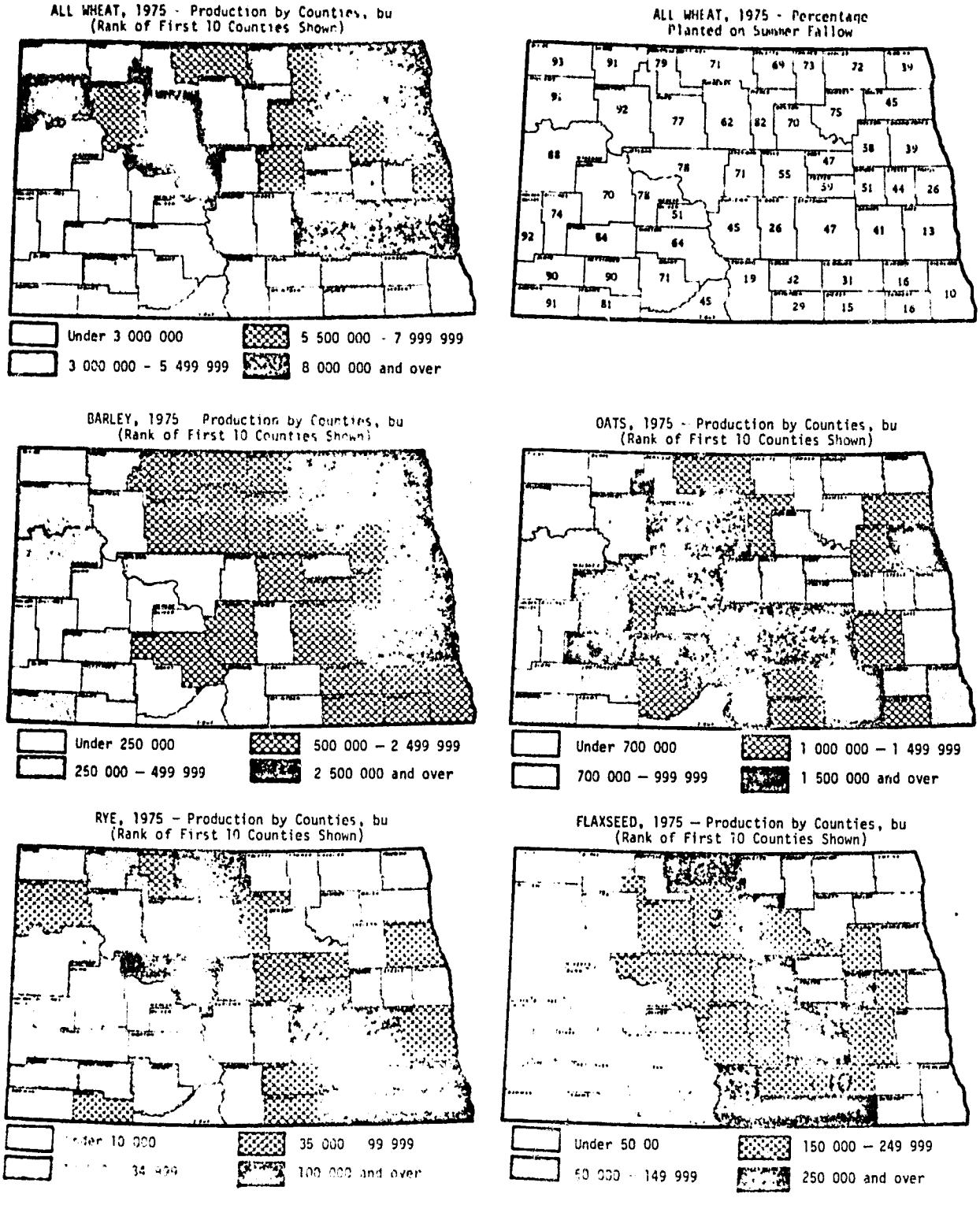


Figure 7.— Production of wheat and other small grains in North Dakota. (From ref. 3.)

small grain in the county in which the segment was located. The 9- by 9-inch full frames were used to check the relationship between the segment and county. (Reference 9 amplifies use of the Landsat full frames.)

3 Looked at the crop calendar (fig. 8) produced by the Yield Estimation Subsystem (YES) and the wheat/small grains separation guidelines to formulate some expected general spectral characteristics (greenness on fig. 5 and brightness) for each small grain.

4. Looked at the spectral plots of the base acquisition showing the classifier-identified picture elements (pixels) of small and nonsmall grains (example shown in fig. 9 for four acquisition dates). Using the knowledge of the historical importance of each small grain in the county and the expected relative greenness and brightness position of each small grain, lines were drawn on the spectral plot to separate classes of small grains. Labeled these small grain classes on the spectral plot (i.e., wheat, barley, oats, etc.) within the boundary lines drawn.

5. Located each of the small grain's pixels (using greenness and brightness values from the spectral plot) in table 4, the listing ordered by dot number.

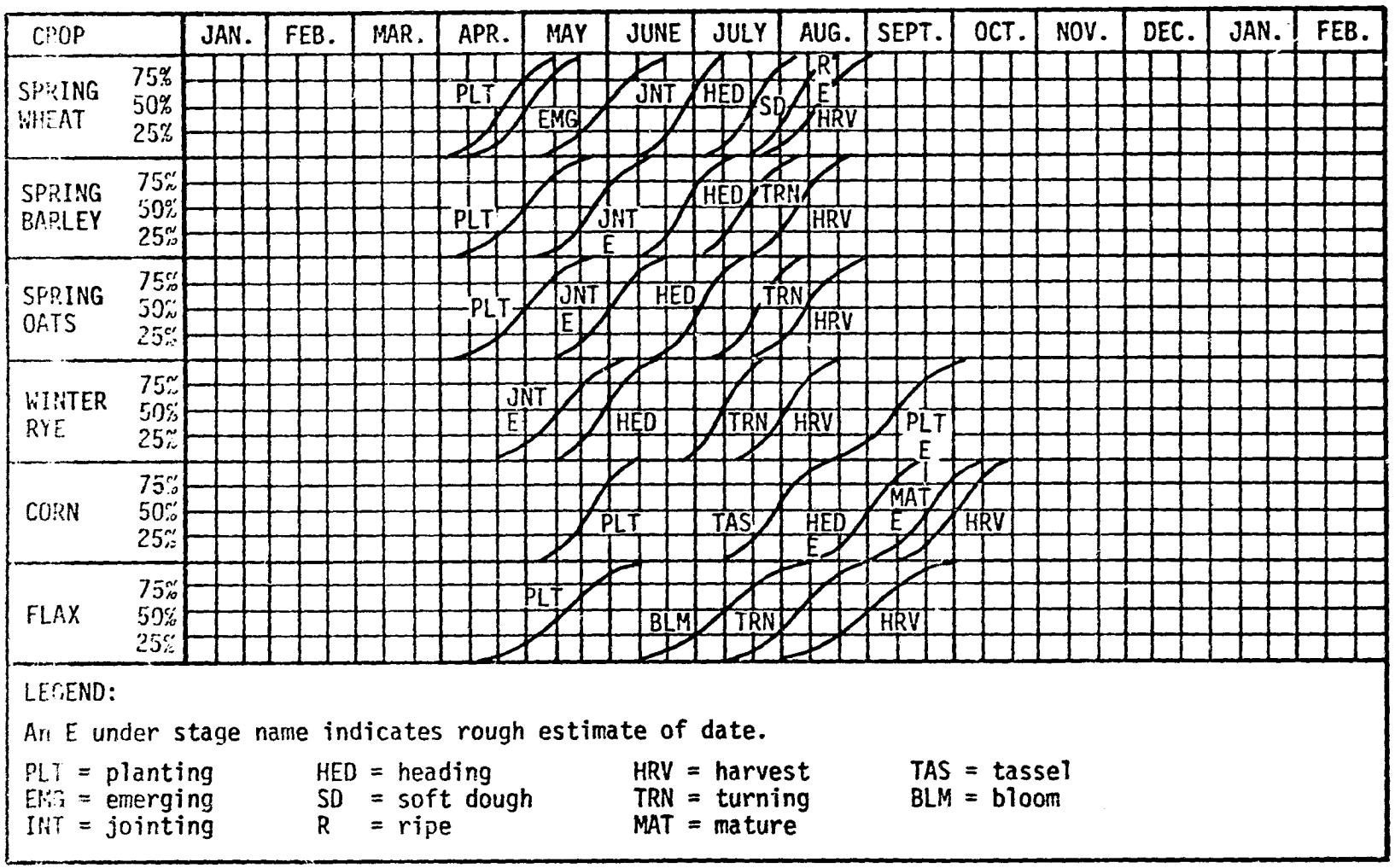
6. Indicated for each pixel classified as a small grain(s) in the listing, to which grain class (wheat, W; barley, B; oats, O; rye, R; etc.)previously indicated on the spectral plot that the specific pixel belonged. Put a symbol (W, B, O, R) to the right of the brightness value of that pixel in the table 4 base acquisition listing.

7. Determined the total number of pixels classified as S in the fourth column of table 4.

8. Tallied the number of S pixels in each grain class (W, B, O, R).

9. Determined the proportion of classified small grains' pixels for the wheat (W) class.

$$\frac{\text{Number of S pixels in the wheat class}}{\text{Total number pixels classified as S}}$$

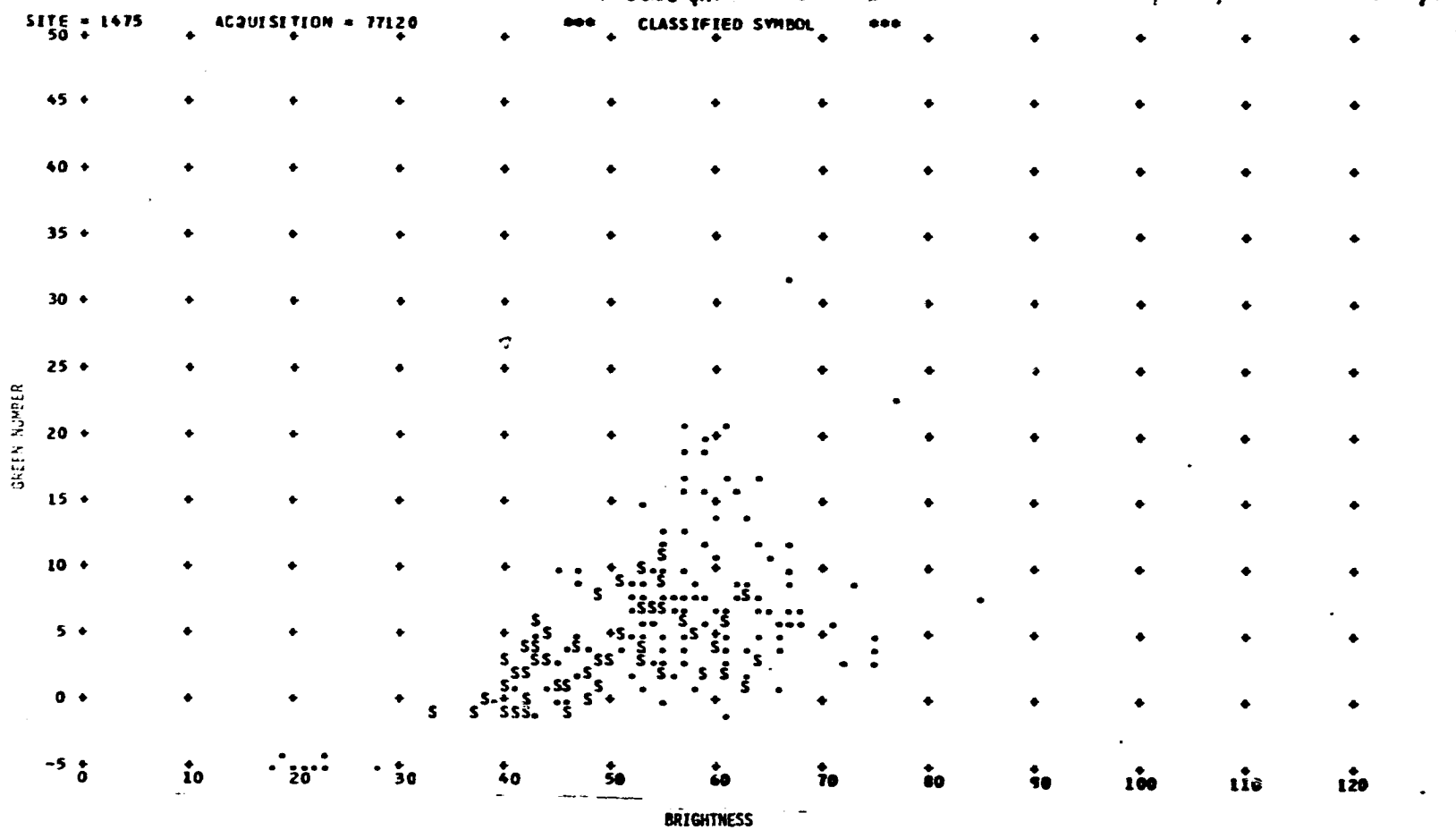


LEGEND:

An E under stage name indicates rough estimate of date.

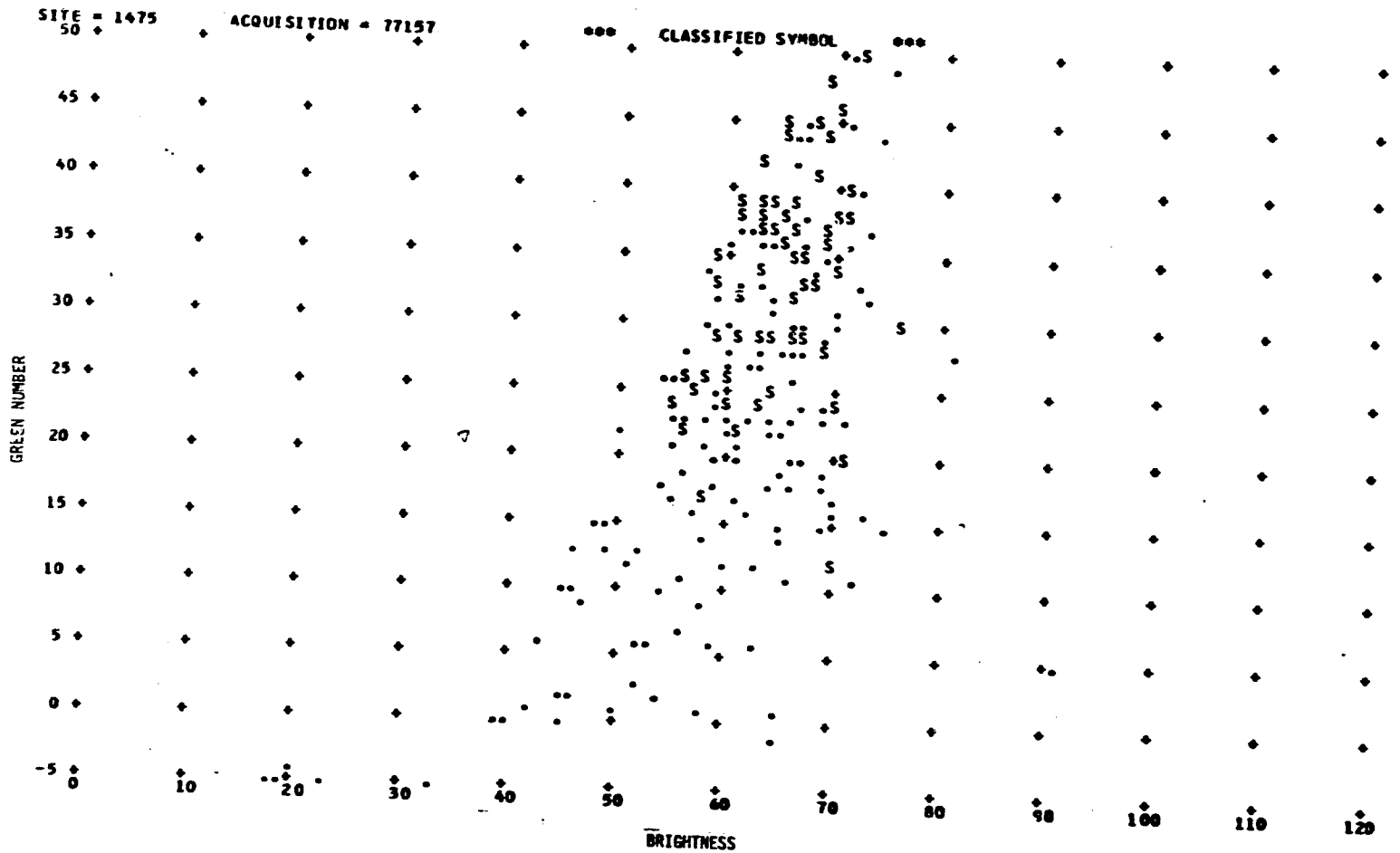
PLT = planting	HED = heading	HRV = harvest	TAS = tassel
EMG = emerging	SD = soft dough	TRN = turning	BLM = bloom
INT = jointing	R = ripe	MAT = mature	

Figure 8.— Nominal crop calendar. (Produced by the YES.)



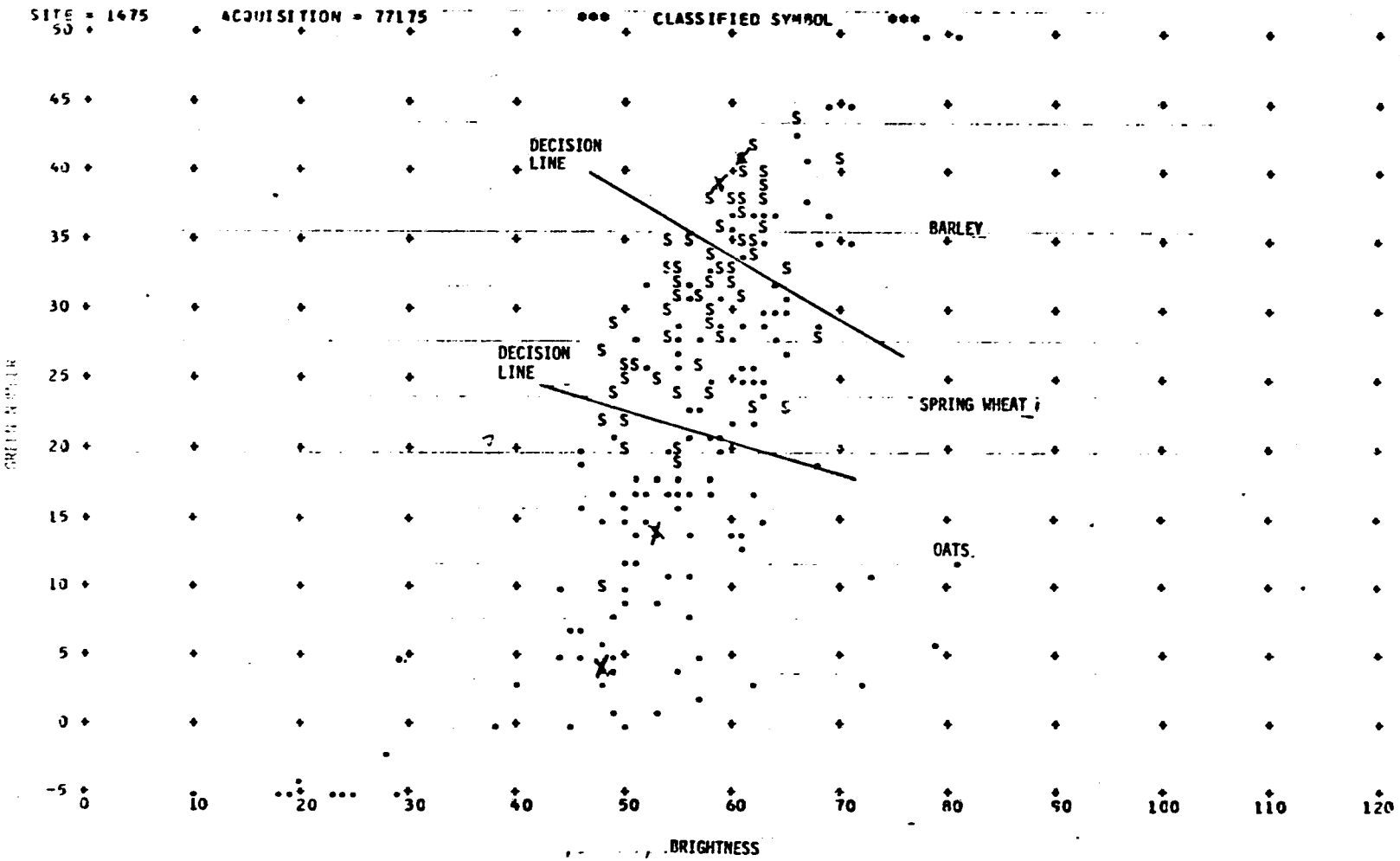
(a) Acquisition date, 77120.

Figure 9.— Scatter plots of classified symbols for segment 1475 (Richland County).



(b) Acquisition date, 77157.

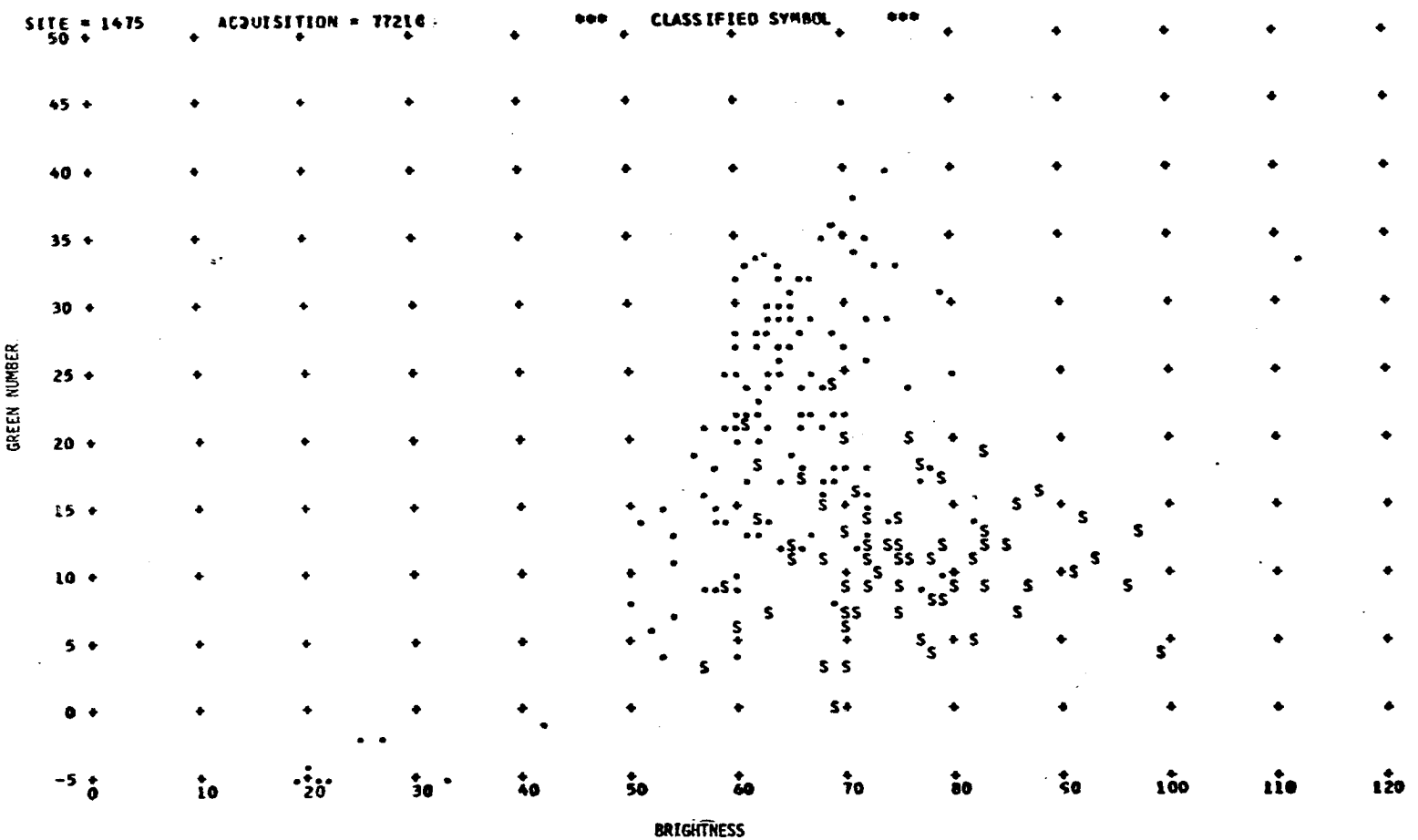
Figure 9.— Continued.



NOTE: S with an X was determined to be nonsmall grains and therefore eliminated from the proportion.

(c) Acquisition date, 77175.

Figure 9.— Continued.



(d) Acquisition date, 77210.

Figure 9.— Concluded.

TABLE 4.— LISTING OF DOT CLASSIFICATION ORDERED BY DOT NUMBER

Dot number	Grid intersections		Analyst label	Classified	Acquisition 1 (77120)		Acquisition 2 (77157)		Acquisition 3 (77175)		Acquisition 4 (77210)	
					G[a]	B[b]	G[a]	B[b]	G[a]	B[b]	G[a]	B[b]
1	10	10	S	S	4	51	35	67	31	61 W	6	70
2	10	20		S	9	67	37	73	31	59	25	67
3	10	30		S	7	53	38	70	36	63 B	27	65
4	10	40		S	4	75	13	52	25	58	23	62
5	10	50	N	N	-7	23	-9	19	-5	29	-6	33
6	10	60		S	-1	46	44	69	32	58 W	9	59
7	10	70	S	S	3	64	33	67	24	58 W	13	57
8	10	80		S	5	44	22	56	26	57 W	8	78
9	10	90		S	4	63	21	58	23	57	21	60
10	10	100		S	8	49	25	57	20	55	13	72
11	10	110	N	N	6	68	17	70	11	54	12	65
12	10	120		S	8	63	28	81	12	81	13	70
13	10	130	N	N	-8	21	-10	23	-8	18	-2	25
14	10	140		S	32	67	32	64	15	63	22	61
15	10	150		S	3	44	17	61	26	50 W	20	70
16	10	160		S	5	58	23	60	26	51 W	14	72
17	10	170		S	12	59	19	56	21	55	17	64
18	10	180		S	20	59	26	54	0	38	14	59
19	10	190		S	-4	23	10	46	3	40	14	51
20	20	10		S	6	53	37	69	33	65 W	21	61
21	20	20	N	N	10	54	35	69	23	55	11	54
22	20	30		S	-5	28	-5	19	-5	24	-6	22
23	20	40	N	N	6	67	16	73	38	63	11	72
24	20	50		S	11	55	37	64	33	59 W	11	65
25	20	60	N	N	5	43	10	45	-9	23	8	50
26	20	70	S	S	1	63	30	76	30	54	3	68
27	20	80		S	2	59	33	68	28	59	11	82
28	20	90		S	7	68	30	66	25	63	21	57
29	20	100	S	S	8	64	45	71	58	81	10	60
30	20	110		S	4	60	28	69	23	65 W	11	78
31	20	120		S	0	55	5	91	3	72	10	79
32	20	130		S	4	46	27	63	38	63	45	70
33	20	140		S	6	61	24	59	18	51	18	58
34	20	150		S	11	65	23	64	22	60	20	60
35	20	160	N	N	6	71	30	70	37	69	33	61
36	20	170		S	4	46	21	55	10	44	18	66
37	20	180	N	N	9	63	20	61	21	58	22	66
38	20	190		S	4	75	22	65	17	56	26	60
39	30	10	N	N	-7	18	-16	33	-9	10	-5	21
40	30	20		S	-4	19	-12	33	-7	19	-4	20
41	30	30	N	N	12	55	23	58	5	46	13	54

[a]Green number.

[b]Brightness value.

TABLE 4.— Continued.

Dot number	Grid intersections		Analyst label	Classified	Acquisition 1 (77120)		Acquisition 2 (77157)		Acquisition 3 (77175)		Acquisition 4 (77210)	
					G[a]	B[b]	G[a]	B[b]	G[a]	B[b]	G[a]	B[b]
42	30	40		A	9	62	28	67	6	79	17	77
43	30	50		A	7	65	28	65	30	63	22	69
44	30	60		A	7	61	32	66	32	60	21	68
45	30	70	N	A	7	64	36	71	37	64	35	72
46	30	80		S	14	63	24	60	33	60W	12	72
47	30	90	S	S	3	43	48	69	38	61B	5	70
48	30	100	N	A	8	62	9	58	19	68	22	70
49	30	110		A	7	61	21	58	22	50	17	68
50	30	120		S	3	54	24	55	22	500	11	72
51	30	130		S	7	55	23	66	28	69W	13	70
52	30	140	S	S	2	52	29	64	32	56W	5	57
53	30	150	N	A	12	67	24	69	29	68	26	64
54	30	160	N	A	1	66	20	59	26	61	21	59
55	30	170	N	A	7	67	26	66	25	61	25	60
56	30	180	N	A	7	60	23	60	26	62	24	66
57	30	190	N	A	7	60	21	61	10	50	15	53
58	40	10	N	A	14	63	31	70	21	59	22	67
59	40	20		A	5	57	16	70	17	62	18	69
60	40	30		S	5	44	29	61	20	500	10	73
61	40	40		A	9	53	30	58	7	45	6	52
62	40	50		A	3	57	1	50	17	58	32	67
63	40	60		A	17	57	33	61	14	56	25	60
64	40	70	N	A	1	40	14	58	56	78	27	65
65	40	80	N	A	13	57	27	63	30	64	40	74
66	40	90		A	8	85	19	69	18	58	20	67
67	40	100	N	A	19	57	37	61	31	56	19	56
68	40	110		A	1	46	13	49	26	52	14	58
69	40	120		A	5	53	0	45	3	48	32	66
70	40	130		A	0	46	12	51	20	46	28	69
71	40	140		S	10	53	36	63	29	55W	16	88
72	40	150		A	6	54	23	56	19	46	33	64
73	40	160		A	12	64	28	63	28	55	32	64
74	40	170	N	A	3	72	22	64	24	63	26	63
75	40	180	N	A	7	68	22	60	27	65	25	59
76	40	190		A	4	66	-1	65	15	48	32	60
77	50	10	N	A	6	66	11	72	30	65	17	69
78	50	20		S	8	49	18	54	17	550	11	76
79	50	30	N	A	5	64	15	75	14	60	14	82
80	50	40		A	5	52	9	47	2	57	33	73
81	50	50		A	3	53	0	40	8	49	30	63
82	50	60		A	16	57	36	60	20	59	13	62
83	50	70	S	S	5	52	20	71	34	62B	5	80
84	50	80		S	5	51	37	66	20	540	14	75
85	50	90	N	A	5	47	18	54	9	53	7	54
86	50	100	S	S	1	49	29	66	27	48W	11	75
87	50	110		A	17	64	44	67	11	56	17	61
88	50	120		A	1	58	19	65	1	53	24	76
89	50	130		A	0	45	6	63	0	45	25	80
90	50	140		S	6	57	26	58	32	60W	15	68
91	50	150	N	A	16	59	23	66	34	61	21	66
92	50	160	N	A	-6	20	-10	18	-4	20	-7	19
93	50	170		A	8	59	31	64	29	59	35	68
94	50	180	N	A	3	75	18	69	25	62	25	63
95	50	190		A	3	61	33	72	35	63	30	65
96	60	10		A	4	47	23	62	16	55	21	63
97	60	20	N	A	1	40	1	58	5	44	27	62

[a]Green number.

[b]Brightness value.

TABLE 4.— Continued.

Dot number	Grid intersections		Analyst label	Classified	Acquisition 1 (77120)		Acquisition 2 (77157)		Acquisition 3 (77175)		Acquisition 4 (77210)	
					G[a]	B[b]	G[a]	B[b]	G[a]	B[b]	G[a]	B[b]
98	60	30	S	S	3	44	37	63	34	58 W	12	85
99	60	40		S	2	52	11	66	45	71	12	64
100	60	50	N	N	9	67	34	68	25	63	4	60
101	60	60	N	N	4	61	3	52	38	67	22	62
102	60	70		N	9	52	42	66	21	59	38	71
103	60	80	S	S	4	42	33	59	33	55 W	12	75
104	60	90		S	2	48	40	71	41	70 B	18	77
105	60	100		S	7	57	2	46	1	49	4	53
106	60	110		S	3	53	36	65	19	55 O	7	75
107	60	120		S	-1	43	29	63	35	61 B	15	65
108	60	130	S	S	1	40	39	64	36	60 B	6	77
109	60	140	N	N	17	61	27	62	29	59	14	69
110	60	150	N	N	-7	22	-4	20	-7	25	-2	27
111	60	160	N	N	5	55	23	71	11	73	29	74
112	60	170	S	S	2	55	38	70	40	61 B	12	65
113	60	180		S	9	62	38	67	41	67	30	64
114	60	190	N	N	5	66	18	59	24	63	13	61
115	70	10		N	10	47	13	46	8	56	5	58
116	70	20	S	S	2	61	34	70	16	50 O	13	83
117	70	30	N	N	5	52	11	56	13	61	22	67
118	70	40		N	4	51	1	42	9	50	28	66
119	70	50		N	21	61	28	66	29	61	16	68
120	70	60		N	8	55	49	75	6	48	5	60
121	70	70		N	7	60	44	74	5	57	8	65
122	70	80		N	3	55	17	55	16	46	22	67
123	70	90	N	N	16	62	18	64	20	54	27	64
124	70	100		N	3	50	1	65	17	52	22	60
125	70	110		N	2	41	10	54	21	49	27	70
126	70	120	S	S	2	56	24	70	26	55 W	20	76
127	70	130	S	S	2	41	39	64	24	49 W	3	57
128	70	140	S	S	2	41	26	60	31	55 W	9	72
129	70	150		S	21	57	14	65	43	66	24	63
130	70	160		S	8	63	29	67	24	55 W	7	70
131	70	170		S	1	44	26	60	22	48 O	3	70
132	70	180	S	S	4	57	35	66	25	53 W	4	78
133	70	190	N	N	8	53	23	55	28	57	15	58
134	80	10		N	4	57	6	53	12	50	17	69
135	80	20		S	2	42	36	69	28	54 W	10	91
136	80	30		S	10	67	16	62	45	71	25	72
137	80	40		S	3	40	39	66	25	50 W	7	63
138	80	50		S	-1	61	24	67	14	61	19	65
139	80	60	N	N	6	59	23	69	5	49	27	65
140	80	70	N	N	10	45	27	60	29	63	29	63
141	80	80		N	3	49	38	65	31	57 W	12	83
142	80	90	N	N	1	53	2	45	17	49	25	64
143	80	100		N	8	55	28	60	32	52	31	65
144	80	110		S	-1	37	45	65	37	61 B	8	79
145	80	120	S	S	0	38	46	70	38	58 B	0	69
146	80	130		S	0	39	38	63	29	49 W	4	99
147	80	140	S	S	1	44	34	58	32	56	-1	42
148	80	150	N	N	2	56	2	46	4	55	28	69
149	80	160	N	N	3	45	6	59	7	46	36	69
150	80	170	N	N	9	58	15	65	37	62	22	62
151	80	180		S	-1	41	46	70	40	63 B	7	86
152	80	190	N	S	4	63	32	59	37	60	33	64
153	90	10		S	6	61	25	64	23	62	12	74

[a]Green number.

[b]Brightness value.

TABLE 4.– Continued.

Dot number	Grid intersections		Analyst label	Classified	Acquisition 1 (77120)		Acquisition 2 (77157)		Acquisition 3 (77175)		Acquisition 4 (77210)	
					G[a]	B[b]	G[a]	B[b]	G[a]	B[b]	G[a]	B[b]
154	90	20	N	N	11	60	15	69	37	63	2[illegible]	72
155	90	30		N	9	51	29	59	30	58 W	[illegible]	75
156	90	40	S	S	7	54	34	63	37	61 B	15	83
157	90	50		S	13	55	52	71	22	62	14	63
158	90	60	S	S	0	42	38	61	39	63 B	[illegible]	82
159	90	70	N	N	14	60	40	72	35	68	15	72
160	90	80	N	N	8	52	6	52	12	51	34	71
161	90	90		N	6	53	25	59	27	55	2[illegible]	65
162	90	100		S	4	43	22	61	29	59 W	24	69
163	90	110		S	3	50	39	63	32	55 W	[illegible]	83
164	90	120		S	0	48	45	68	36	59 B	12	79
165	90	130	S	S	1	46	39	63	35	62 B	7	71
166	90	140		N	1	41	15	48	12	51	1[illegible]	72
167	90	150		N	-1	43	22	50	-2	28	[illegible]	77
168	90	160	N	N	8	57	42	66	35	68	2[illegible]	64
169	90	170	N	N	10	57	37	62	17	51	2[illegible]	67
170	90	180	N	N	2	63	7	56	3	62	24	61
171	90	190		N	4	63	29	69	35	71	24	66
172	100	10		N	8	55	17	61	16	50	1[illegible]	72
173	100	20		N	8	58	41	68	28	60	1[illegible]	71
174	100	30	N	N	9	67	2[illegible]	66	25	62	14	74
175	100	40		N	11	65	36	67	31	65	18	70
177	100	60		S	5	51	39	61	33	54 W	11	93
178	100	70	S	S	7	52	54	72	35	56	14	92
179	100	80	S	N	15	53	36	63	36	60	18	78
180	100	90		N	5	75	20	67	45	69	25	64
181	100	100		S	-1	33	32	66	42	62 B	14	62
182	100	110		S	6	43	41	68	38	60 B	17	79
183	100	120	S	S	3	38	38	71	44	66 B	[illegible]	96
184	100	130	N	N	7	52	33	63	15	50	1[illegible]	58
185	100	140		N	9	47	12	63	34	61	24	68
186	100	150		N	2	47	45	67	26	55	21	63
187	100	160	S	S	1	45	42	63	33	54 W	[illegible]	75
188	100	170		N	9	67	30	67	33	58	13	72
190	100	190		N	3	54	28	56	14	51	20	60
191	110	10	N	N	23	77	32	73	28	64	12	71
193	110	30	N	N	4	57	2	54	15	52	12	66
194	110	40		N	7	56	12	60	29	55	31	79
196	110	60		S	9	55	38	63	38	63 B	17	66
197	110	70		S	8	56	6	43	32	64	32	73
198	110	80	N	N	13	57	30	60	31	56	2[illegible]	67
199	110	90		N	19	59	44	66	18	55	13	72
200	110	100	N	N	4	48	15	49	0	50	27	70
201	110	110		N	10	55	36	64	17	55	13	67
202	110	120		N	4	48	0	39	28	51	33	75
203	110	130		S	-1	42	32	61	10	48 O	11	68
204	110	140		S	0	39	16	57	4	49	[illegible]	57
205	110	150	S	S	0	38	26	56	29	49 W	[illegible]	70
206	110	160		N	4	55	26	55	18	53	27	60
207	110	170		N	5	61	18	66	17	54	24	63
208	110	180		N	9	73	31	64	21	58	1[illegible]	57
209	110	190	S	S	-1	41	35	59	35	54 W	[illegible]	60

[a]Green number.

[b]Brightness value.

TABLE 4.— Concluded.

Total number of S pixels labeled W, B, and O.	59
S pixels labeled W.	33
S pixels labeled B.	18
S pixels labeled O.	8
Total number of S pixels divided by total number of W pixels, P(W) 33/59.	0.5593
BCE of small grains, %.	36
Direct wheat estimate achieved, %	20.1
Difference between BCE and wheat estimate, % of other small grains.	15.9

10. Determined the percentage of spring wheat for the segment.

$$(P_W)(\%S_{BCE}) = \text{percentage of spring wheat}$$

where

P_W = proportion of spring wheat

S_{BCE} = bias-corrected estimate for grains

11. Subtracted the percentage of spring wheat from the BCE to obtain the percentage of other spring small grains in the segment.

12. Recorded the proportions of spring wheat and other small grains on the CAMS evaluation form and Porta-punch cards.

13. Recorded all other information in the necessary places, put packet contents together in proper manner, and turned packet over to the spring wheat/small grains coordinator (D. R. Thompson and J. D. O'Connell, personal communication.)

3.1.3 DEVIATIONS FROM THE PROCEDURE

The analysts deviated from the established procedure on points 4 and 6. In reference to point 4, base acquisition was not defined; therefore, wheat was separated from other small grains on the acquisition that appeared to show separability. The green number growth plot of the small grains (fig. 5), the separation guidelines, the crop calendar (fig. 8), and scatter plots (fig. 9) provided the bases for determining the acquisition to use in separation.

Point 6 directed the analyst to label all pixels classified as being small grains with W, B, O, or R. The dots classified S that the analyst determined by interpretation of the imagery as being nonsmall grains were eliminated from the proportion. North Dakota was processed as a spring grain state; and because rye is primarily a winter grain, it was classified as nonsmall grain. No rye was labeled.

3.1.4 IMPLEMENTATION OF THE PROCEDURE

Segment 1475 (Richland County) shows how the direct wheat procedure was implemented. Using Procedure 1 as described in reference 9, the analyst obtained a satisfactory spring grains' BCE of 36 percent.

North Dakota crop acreage data were removed from the operational segment packets to eliminate analyst bias in separating the grains. Production maps (fig. 7) were provided as a guide on the importance of the grains in the county. Thus, the figure indicates that in 1975, Richland County farmers produced 3 to 5.5 million bushels of wheat, 0.5 to 2.5 million bushels of barley, and 0.7 to 1 million bushels of oats.

The full-frame data (CAMS 9- by 9-inch files) were checked to ascertain how representative the segment is of the county. In this example, the segment represents the southwest part of the county only.

The crop calendar (fig. 8) was consulted to determine crop development stage. The YES computed an adjustment to the nominal wheat crop calendar. Table 5 summarizes the crop calendar information available to the analyst.

After reviewing the separation guidelines, the green number growth patterns for all acquisition dates (fig. 5), the crop calendar information, and the scatter plots (fig. 9), the analyst determined which acquisition displayed the most separability of the spring small grains. Decision lines [fig. 9(c)] were drawn on the chosen scatter plot where a natural break in the data appeared. The lines separate wheat from barley and oats.

Using table 4, the analyst located each of the pixels classified S (spring small grains) on figure 9 (c), and the appropriate label (W, B, or O) was written to the right of the brightness value for the separation acquisition. The analyst verified questionable S-classified pixels with the imagery and omitted those pixels interpreted as nonsmall grains. The number of S pixels labeled W, B, or O were tallied (59) and divided by the total number of W pixels (33). (See last page of table 4). The BCE of the small grains

TABLE 5.— CROP DEVELOPMENT STAGES FOR SEGMENT 1475

Julian date	Calendar date	Robertson scale[a] for wheat		Robertson scale[a] for barley (nominal)	Robertson scale[a] for oats (nominal)
		Adjustable	Nominal		
7120	4/30/77	1.2	1.9	1.0	1.0
7157	6/6/77	3.5	3.3	3.3	3.2
7175	6/24/77	4.3	3.9	3.9	3.8
7210	7/29/77	>6.0	5.6	5.2	4.9

[a]Robertson scale at 50-percent point, where
1.0 = Planting
2.0 = Emerging
3.0 = Jointing
4.0 = Heading
5.0 = Soft dough
6.0 = Ripe
7.0 = Harvest

(36 percent) was multiplied by the proportion of spring wheat (0.5593) to achieve a direct wheat estimate (20.1 percent spring wheat). The difference between the BCE and the wheat estimate is the percentage of other small grains (15.9 percent) in the segment.

3.1.5 PROBLEMS ENCOUNTERED IN PROCEDURE IMPLEMENTATION

The analyst, according to procedure, could apply separation labels only to those pixels classified S. Occasionally, a spring grain signature was classified N (nonsmall grain) because the signature did not have a type 1 dot label or because the signature was in a mixed cluster and misclassified. That signature may have had an S-type two-dot label; but because of the N classification, the analyst could not apply a separation label. The accuracy of the machine classification was very important in the direct wheat procedure.

A poor acquisition history was a serious problem for 4 of the 18 blind sites in North Dakota (see appendix B). Adequate acquisition history is vital in obtaining the best possible small-grain estimate. In the subsequent study, the coverage during the heading to ripening stages was found to be critical in separation of barley from wheat and oats. Segment registration between acquisitions was critical to the correct labeling of border pixels; a substantial error was related to misregistration and border pixels.

3.1.6 USE OF THE PRODUCTION MAP IN THE PROCEDURE

The production maps (fig. 7) were utilized as a guide to the importance of certain crops in a given county. The estimate determined in CAMS operations was a percentage of the total segment acreage rather than production (yield × acreage). Yield as related to total production is variable among different small grain crops as well as among counties for the same crop. During North Dakota segment processing, the assumption was made that these variances were not significant.

Table 6 (refs. 7 and 8) lists examples of potentially misleading data for four counties (Barnes, Bowman, Sargent, and Ward). A discussion of each county follows.

1. Barnes County: Figure 7 shows that wheat and barley exceed the production category limit, but there is no indication that the wheat acreage is nearly three times that of barley.

2. Bowman County: In 1975, 15 700 acres of winter wheat were harvested. Figure 7 does not relate this information. In North Dakota, winter grains are labeled non-spring small grains. The LACIE Phase III blind site ground-truth information for the Bowman County segment indicated that 45 percent of the small grain dots were winter wheat, 40 percent spring wheat, and 15 percent barley and oats.

3. Sargent County: Barley and oats occupied approximately the same number of acres in 1975. The categories of 0.5 to 2.5 million bushels of barley and 1.0 to 1.5 million bushels of oats are misleading.

4. Ward County: Oat production could be less than, equal to, or greater than barley production. Wheat production is probably much greater than oats, but an accurate, informative picture has not been made available.

Specific crop acreages for a 5-year period, total agricultural acreage, and county acreage in conjunction with full-frame coverage best assist the analyst in determining crop importance in the segment to be worked. Appendix C provides additional acreage information.

3.2 STATISTICAL EVALUATION AND ANALYSIS

A statistical evaluation was made to determine the accuracy of the LACIE Phase III direct wheat procedure. The following questions were posed for evaluation.

1. How accurately was the machine able to classify the 209 dots? (Table 7.)

2. How accurately were the analysts able to label spring wheat dots that were classified as small grains? (Table 8.)

TABLE 6.— COMPARISON OF 1975 PRODUCTION AND HARVESTED ACREAGES

[From refs. 7 and 8]

County	Production, million bushels (a)			1975 harvested acreage					Agricultural (1974), acres	County acreage
	All wheat	Barley	Oats	All wheat	Spring wheat	Durum wheat	Barley	Oats		
Barnes	8.0+	2.5+	1.0 – 1.5	293 400	234 000	57 500	103 700	28 200	795 843	946 624
Bowman	-3.0	0.25 – 0.5	0.7 – 1.0	111 300	70 400	25 200	10 400	22 400	356 938	744 320
Sargent	-3.0	0.5 – 2.5	1.0 – 1.5	104 600	71 600	32 400	29 500	29 700	415 919	545 856
Ward	8.0+	0.5 – 2.5	1.5+	380 700	112 500	267 400	26 200	40 200	959 280	1 308 160

[a]From figure 7.

3. How accurately were the analysts able to label spring wheat dots? (Table 9.)

4. The direct wheat procedure assumed that the ratio of wheat to small grains was the same for those pixels classified as small grains as it was for those pixels classified as nonsmall grains. To what extent was this assumption tenable? (Table 10.)

5. Were the accuracies obtained for discriminating wheat from other small grains greater than those from random chance? (Table 11.)

6. How well did the wheat proportion estimates agree with the ground-truth wheat proportions? (D. T. Register, personal communication, Apr. 1978.) (Table 12.)

The answers to these questions as quantified in tables 7 through 12 are discussed in section 3.2.3. The results are given for each CRD, AI keys partition, final separation acquisition, APU, and overall for the state.

3.2.1 DATA SET

Two sets of ground truth for the 209 dots were available for evaluation. The Accuracy Assessment (AA) section prepared universal format ground-truth files registered to the Landsat imagery for acceptable segments (as defined in section 2.1). The crop codes on the ground-truth files corresponding to the 209 pixels on the Landsat imagery comprised a set of ground-truth labels used for comparison. See reference 10 for documentation of ground-truth file creation.

A second set of ground-truth labels was obtained by analyst examination and interpretation of the ground-truth field overlay, aerial color infrared photographs, and the Landsat imagery. The analysts visually correlated field location and correct labeling for the 209 dots. The results are presented using both sets of ground truth.

3.2.2 RESULTS AND DISCUSSION

Table 7(a) shows the average accuracy of machine classification for the 209 [illegible] by CRD, key partition, acquisition date, and APU. Low (35.3 percent)

TABLE 7.— DIRECT EVALUATION RESULTS OF DOT CLASSIFICATION

(a) Accuracy of machine classification obtained with analyst ground truth.

Group	Sample size	P9 (a)	P10 (b)	P11 (c)	P12 (d)
Crop reporting dist. 1	3	0.532	0.832	0.734	0.908
Crop reporting dist. 3	4	.844	.838	.809	.791
Crop reporting dist. 4	2	.579	.820	.894	.979
Crop reporting dist. 5	2	.353	.703	.785	.955
Crop reporting dist. 6	1	.879	.870	.880	.890
Crop reporting dist. 7	3	.533	.730	.802	.911
Crop reporting dist. 9	3	.724	.905	.825	.892
Key partition 21	1	0.841	0.906	0.919	0.957
Key partition 24	4	.834	.868	.849	.843
Key partition 25	3	.674	.844	.762	.861
Key partition 26	6	.569	.739	.822	.912
Key partition 27	1	.624	.828	.794	.911
Key partition 29	3	.406	.731	.743	.920
Acquisition date[e] 140	1	0.422	0.790	0.617	0.860
Acquisition date[e] 150	3	.521	.690	.764	.880
Acquisition date[e] 170	8	.744	.791	.836	.853
Acquisition date[e] 190	6	.588	.863	.827	.956
Agrophysical unit 19	6	0.645	0.781	0.806	0.886
Agrophysical unit 20	4	.780	.885	.812	.848
Agrophysical unit 21	8	.560	.768	.809	.918
Overall	18	0.626	0.792	0.802	0.888

[a]P9 = Pr(M = SG/GT = SG) — Probability that the machine classified small grains given that the ground truth is small grains.
[b]P10 = Pr(GT = SG/M = SG) — Probability that the ground truth is small grains given that the machine classified small grains.
[c]P11 = Pr(correct classification) — Probability of correct classification.
[d]P12 = Pr(M = N/GT = N) — Probability that the machine classified nonsmall grains given that the ground truth is nonsmall grains.
[e]Acquisition dates are given in 10-day increments.

and moderately high (87.9 percent) accuracies were observed for segments from CRD 5 and CRD 6, respectively. Variability was less in accuracies from the key partitions compared to the variability in accuracies from the CRDs. Partition 29 had a relatively low (40.6 percent) accuracy, but small-grain dots from partition 21 classified 84.1 percent correctly. Machine classification accuracies improved with more acquisitions, and accuracies were better for segments classified using later dates. There was not much difference between accuracies among the APUs. The overall accuracy for the 18 segments averaged to 62.6 percent for small grains and 88.8 percent for nonsmall grains. Similar trends were observed from results [table 7(b)] obtained with AA tape ground truth.

In table 8(a), the accuracy of labeling spring wheat dots classified as small grains is presented along with the accuracies of labeling spring grain dots classified and ground truth identified as small grains. The labeling accuracies for small grains were over 95 percent in most cases except for APU 19, which was rather low (22.8 percent). Higher accuracies indicate that the analysts were able to identify and label spring wheat dots more accurately if segments were grouped according to key partitions rather than by CRDs, by APU, or by acquisition dates. Because of confusion and difficulty in separating wheat, barley, and other small grains, the overall correct labeling percentage was very low (52.8 percent). Slightly better results were obtained from data using the analyst ground truth than the results obtained from data using the AA ground truth [table 8(b)].

The accuracies for labeling spring wheat dots based on the analyst ground truth and the AA tape ground truth are presented on tables 9(a) and 9(b), respectively. The accuracies for correct labeling were 59.1 percent for spring wheat dots and 94.1 percent for nonsmall-grain dots. The probabilities for correct labeling of spring wheat dots given that they are small grains were less than 50 percent.

The ratios of spring wheat to small grains for dots classified as small grains [illegible] ratios of spring wheat to small grains for dots classified as

TABLE 7.— Concluded.

(b) Accuracy of machine classification obtained with AA tape ground truth.

Group	Sample	P9 (a)	P10 (b)	P11 (c)	P12 (d)
Crop reporting dist. 1	3	0.516	0.764	0.721	0.879
Crop reporting dist. 3	4	.821	.830	.796	.772
Crop reporting dist. 4	2	.393	.607	.848	.953
Crop reporting dist. 5	2	.355	.639	.815	.954
Crop reporting dist. 6	1	.830	.830	.837	.844
Crop reporting dist. 7	3	.533	.431	.793	.846
Crop reporting dist. 9	3	.671	.770	.790	.859
Key partition 21	1	0.797	0.859	0.900	0.903
Key partition 24	4	.804	.850	.821	.822
Key partition 25	3	.659	.845	.765	.844
Key partition 26	6	.498	.514	.797	.867
Key partition 27	1	.600	.682	.756	.843
Key partition 29	3	.396	.660	.748	.909
Acquisition date[e] 140	1	0.429	0.774	0.627	0.856
Acquisition date[e] 150	3	.493	.607	.750	.844
Acquisition date[e] 170	8	.709	.732	.814	.828
Acquisition date[e] 190	6	.531	.681	.812	.911
Agrophysical unit 19	6	0.615	0.736	0.796	0.865
Agrophysical unit 20	4	.756	.861	.788	.821
Agrophysical unit 21	8	.507	.684	.791	.877
Overall	18	0.598	0.696	0.792	0.861

[a]P9 = Pr(M = SG/GT = SG) — Probability that the machine classified small grains given that the ground truth is small grains.
[b]P10 = Pr(GT = SG/M = SG) — Probability that the ground truth is small grains given that the machine classified small grains.
[c]P11 = Pr(correct classification) — Probability of correct classification
[d]P12 = Pr(M = N/GT = N) — Probability that the machine classified nonsmall grains given that the ground truth is nonsmall grains.
[e]Acquisition dates are given in 10-day increments.

TABLE 8.— DIRECT WHEAT EVALUATION RESULTS OF LABELING SPRING WHEAT CLASSIFIED AS SMALL GRAINS

(a) Results obtained with analyst ground truth.

Group	Sample size	P5 (a)	P6 (b)	P7 (c)	P8 (d)
Crop reporting dist. 1	3	0.763	0.957	0.853	0.578
Crop reporting dist. 3	4	.652	.972	.886	.558
Crop reporting dist. 4	2	.687	.976	.847	.482
Crop reporting dist. 5	2	.789	.898	.810	.608
Crop reporting dist. 6	1	.845	1.000	.916	.600
Crop reporting dist. 7	3	.791	.992	.797	.352
Crop reporting dist. 9	3	.795	.962	.832	.505
Key partition 21	1	0.800	0.983	0.919	0.516
Key partition 24	4	.816	.972	.909	.559
Key partition 25	3	.825	.950	.883	.578
Key partition 26	6	.759	.980	.794	.428
Key partition 27	1	.930	.964	.828	.606
Key partition 29	3	.693	.934	.808	.566
Acquisition date[e] 140	1	0.674	1.000	0.803	0.516
Acquisition date[e] 150	3	.850	.943	.776	.559
Acquisition date[e] 170	8	.798	.981	.827	.502
Acquisition date[e] 190	6	.772	.949	.912	.638
Agrophysical unit 19	6	0.687	0.228	0.837	0.554
Agrophysical unit 20	4	.826	.966	.920	.558
Agrophysical unit 21	8	.775	.967	.815	.560
Overall	18	0.791	0.965	0.846	0.528

[a]P5 = Pr(AI = SW/GT = SW and M = SG) — Probability that the AI labeled spring wheat given that the ground truth is spring wheat and the machine classified small grains.

[b]P6 = Pr(AI = SG/GT = SG and M = SG) — Probability that the AI labeled small grains given that the ground truth is small grains and the machine classified small grains.

[c]P7 = Pr(GT = SG/AI = SG and M = SG) — Probability that the ground truth is small grains given that the AI labeled small grains and the machine classified small grains.

[d]P8 = Pr(correct labeling over all) — Probability of correct labeling over all.

[e]Acquisition dates are given in 10-day increments.

TABLE 8.— Concluded.

(b) Results obtained with AA tape ground truth.

Group	Sample size	P5 (a)	P6 (b)	P7 (c)	P8 (d)
Crop reporting dist. 1	3	0.746	0.944	0.772	0.507
Crop reporting dist. 3	4	.833	.912	.862	.529
Cron reporting dist. 4	2	.667	.967	.599	.343
Crop reporting dist. 5	2	.770	.879	.713	.585
Crop reporting dist. 6	1	.830	1.000	.874	.540
Cron reporting dist. 7	3	.693	.988	.476	.335
Crop reporting dist. 9	3	.813	.966	.799	.500
Key partition 21	1	0.848	0.982	0.871	0.516
Key partition 24	4	.811	.922	.881	.525
Key partition 25	3	.817	.944	.882	.584
Key partition 26	6	.702	.974	.545	.362
Key partition 27	1	.914	.956	.672	.485
Key partition 29	3	.708	.912	.702	.503
Acquisition date[e] 140	1	0.658	1.000	0.787	0.484
Acquisition date[e] 150	3	.825	.927	.666	.502
Acquisition date[e] 170	8	.762	.953	.754	.448
Acquisition date[e] 190	6	.761	.938	.712	.494
Agrophysical unit 19	6	0.773	0.945	0.773	0.512
Agrophysical unit 20	4	.822	.916	.886	.527
Agrophysical unit 21	8	.738	.967	.613	.420
Overall	18	0.766	0.946	0.727	0.474

[a]P5 = Pr(AI = SW/GT = SW and M = SG) — Probability that the AI labeled spring wheat given that the ground truth is spring wheat and the machine classified small grains.
[b]P6 = Pr(AI = SG/GT = SG and M = SG) — Probability that the AI labeled small grains given that the ground truth is small grains and the machine classified small grains.
[c]P7 = Pr(GT = SG/AI = SG and M = SG) — Probability that the ground truth is small grains given that the AI labeled small grains and the machine classified small grains.
[d]P8 = Pr(correct labeling over all) — Probability of correct labeling over all.
[e]Acquisition dates are given in 10-day increments.

TABLE 9.— DIRECT WHEAT EVALUATION RESULTS OF ANALYST LABELING SPRING WHEAT DOTS

(a) Results obtained with analyst ground truth.

Group	Sample size	P1 (a)	P2 (b)	P3 (c)	P4 (d)
Crop reporting dist. 1	3	0.561	0.904	0.657	0.420
Crop reporting dist. 3	4	.770	.923	.683	.550
Crop reporting dist. 4	2	.514	.981	.871	.458
Crop reporting dist. 5	2	.419	.955	.740	.344
Crop reporting dist. 6	1	.720	.943	.763	.525
Crop reporting dist. 7	3	.450	.932	.778	.368
Crop reporting dist. 9	3	.693	.971	.791	.444
Key partition 21	1	0.706	0.972	0.828	0.464
Key partition 24	4	.708	.951	.719	.509
Key partition 25	3	.736	.937	.746	.508
Key partition 26	6	.499	.950	.811	.426
Key partition 27	1	.805	.892	.750	.647
Key partition 29	3	.362	.917	.611	.266
Acquisition date[e] 140	1	0.478	0.820	0.553	0.250
Acquisition date[e] 150	3	.526	.936	.676	.396
Acquisition date[e] 170	8	.628	.934	.742	.450
Acquisition date[e] 190	6	.591	.972	.812	.498
Agrophysical unit 19	6	0.555	0.927	0.696	0.391
Agrophysical unit 20	4	.718	.949	.684	.495
Agrophysical unit 21	8	.554	.947	.811	.463
Overall	18	0.591	0.941	0.741	0.474

[a]P1 = Pr(AI = SW/GT = SW) — Probability that the AI labeled spring wheat given that the ground truth is spring wheat.
[b]P2 = Pr(AI = N/GT = N) — Probability that the AI labeled nonsmall grains given that the ground truth is nonsmall grains.
[c]P3 = overall accuracy — overall accuracy of labeling.
[d]P4 = Pr(correct label/GT = SG) — Probability of correct labeling given that the ground truth is small grains.
[e]Acquisition dates are given in 10-day increments.

TABLE 9.— Concluded.

(b) Results obtained with AA tape ground truth.

Group	Sample size	P1 (a)	P2 (b)	P3 (c)	P4 (d)
Crop reporting dist. 1	3	0.520	0.844	0.581	0.388
Crop reporting dist. 3	4	.696	.859	.510	.462
Crop reporting dist. 4	2	.425	.956	.853	.355
Crop reporting dist. 5	2	.477	.934	.767	.373
Crop reporting dist. 6	1	.621	.940	.731	.488
Crop reporting dist. 7	3	.351	.870	.779	.268
Crop reporting dist. 9	3	.634	.943	.760	.433
Key partition 21	1	0.765	0.944	0.818	0.500
Key partition 24	4	.638	.901	.665	.430
Key partition 25	3	.742	.924	.573	.520
Key partition 26	6	.407	.901	.796	.330
Key partition 27	1	.692	.725	.648	.562
Key partition 29	3	.348	.891	.583	.246
Acquisition date[e] 140	1	0.500	0.852	0.606	0.275
Acquisition date[e] 150	3	.483	.878	.658	.343
Acquisition date[e] 170	8	.589	.898	.661	.411
Acquisition date[e] 190	6	.511	.910	.750	.411
Agrophysical unit 19	6	0.524	0.908	0.591	0.375
Agrophysical unit 20	4	.667	.887	.630	.276
Agrophysical unit 21	8	.489	.891	.788	.394
Overall	18	0.540	0.895	0.687	0.392

[a]P1 = Pr(AI = SW/GT = SW) — Probability that the AI labeled spring wheat given that the ground truth is spring wheat.
[b]P2 = Pr(AI = N/GT = N) — Probability that the AI labeled nonsmall grains given that the ground truth is nonsmall grains.
[c]P3 = overall accuracy — overall accuracy of labeling.
[d]P4 = Pr(correct label/GT = SG) — Probability of correct labeling given that the ground truth is small grains.
[e]Acquisition dates are given in 10-day increments.

nonsmall grains are shown in table 10(a) and table 10(b). The Student's t-test showed that the ratios are equal (the difference between the ratios is not significantly different from zero at the 5-percent level).

To test whether the accuracies obtained for discriminating small grains from nonsmall grains were greater than those from random chance, the average performance was computed and the values were tabulated. Results [table 11(a)] showed that the accuracies from analyst labeling in discriminating small grains from nonsmall grains are 64.6 percent better (over all 18 segments) than random chance. Likewise, the data with AA tape ground truth from table 11(b) showed 54.4-percent improvement with analyst labeling over random chance in discriminating small grains from nonsmall grains. However, the accuracies [table 11(c) and table 11(d)] obtained for discriminating wheat from nonwheat were 46.4 percent and 37.0 percent better than random chance for results with analyst ground truth as well as those with accuracy assessment tape ground truth, respectively.

Table 12 presents the wheat and small grains proportion estimates along with the corresponding actual or ground-truth percentages. Average percentages of small grains were significantly underestimated for segments in key partition 29, with latest acquisition dates and over all 18 segments. Similarly, percentage spring wheat estimates were significantly understated for segments in the last APU and those in the 190-acquisition dates.

3.2.3 SUMMARY OF FINDINGS

A large number of the barley and oat pixels was incorrectly labeled spring wheat, whereas only a small number of spring wheat pixels was incorrectly labeled other small grains. As a result, ratios of wheat to other small grains were biased high.

The ratio of wheat to small grains for those pixels classified as small grains was not significantly different from the same ratio for those pixels classified as nonsmall grains. Analyst labeling accuracies were significantly better than random chance.

TABLE 10.-- DIRECT WHEAT EVALUATION RESULTS ASSUMING THE RATIO OF SW TO SG IS THE SAME FOR THOSE PIXELS CLASSIFIED SG AS IT IS FOR THOSE PIXELS CLASSIFIED AS NONSMALL GRAINS

(a) Obtained with analyst ground truth.

Group	Sample size	SW/SG given SG (a)	SW/SG given N (b)
Crop reporting dist. 1	3	0.848	0.681
Crop reporting dist. 3	4	.637	.606
Crop reporting dist. 4	2	.821	.682
Crop reporting dist. 5	2	.781	.824
Crop reporting dist. 6	1	.667	.583
Crop reporting dist. 7	3	.838	.834
Crop reporting dist. 9	3	.690	.795
Key partition 21	1	0.603	0.781
Key partition 24	4	.646	.668
Key partition 25	3	.728	.577
Key partition 26	6	.822	.787
Key partition 27	1	.781	.844
Key partition 29	3	.820	.722
Acquisition date[c] 140	1	0.878	0.358
Acquisition date[c] 150	3	.715	.734
Acquisition date[c] 170	8	.670	.703
Acquisition date[c] 190	6	.861	.794
Agrophysical unit 19	6	0.730	0.705
Agrophysical unit 20	4	.647	.617
Agrophysical unit 21	8	.822	.781
Overall	18	.753	.719

[a]SW/SG given SG = actual ratio of spring wheat to small grains (for dots classified as small grains).
[b]SW/SG given N = actual ratio of spring wheat to small grains (for dots classified as nonsmall grains).
[c]Acquisition dates are given in 10-day increments.

TABLE 10.— Concluded.

(b) Obtained with AA tape ground truth.

Group	Sample size	SW/SG given SG (a)	SW/SG given N (b)
Crop reporting dist. 1	3	0.837	0.697
Crop reporting dist. 3	4	.635	.686
Crop reporting dist. 4	2	.850	.183
Crop reporting dist. 5	2	.807	.747
Crop reporting dist. 6	1	.639	.824
Crop reporting dist. 7	3	.761	.806
Crop reporting dist. 9	3	.691	.741
Key partition 21	1	0.600	0.643
Key partition 24	4	.631	.698
Key partition 25	3	.746	.592
Key partition 26	6	.795	.779
Key partition 27	1	.778	.900
Key partition 29	3	.816	.670
Acquisition date[c] 140	1	0.854	0.375
Acquisition date[c] 150	3	.721	.702
Acquisition date[c] 170	8	.671	.726
Acquisition date[c] 190	6	.829	.750
Agrophysical unit 19	6	0.727	0.695
Agrophysical unit 20	4	.636	.594
Agrophysical unit 21	8	.806	.781
Overall	18	0.742	0.711

[a]SW/SG given SG = actual ratio of spring wheat to small grains (for dots classified as small grains).
[b]SW/SG given N = actual ratio of spring wheat to small grains (for dots classified as nonsmall grains).
[c]Acquisition dates are given in 10-day increments.

TABLE 11.- DIRECT WHEAT EVALUATION RESULTS OF A TEST TO DETERMINE WHETHER ACCURACIES FOR DISCRIMINATING SMALL GRAINS FROM NONSMALL GRAINS ARE GREATER THAN THAT FOR RANDOM CHANCE

(a) Accuracies obtained with analyst ground truth.

Group	Sample size	Average performance (a)	Standard deviation
Crop reporting dist. 1	3	[b]0.478	0.248
Crop reporting dist. 3	4	[c]0.756	0.211
Crop reporting dist. 4	2	[b]0.633	0.183
Crop reporting dist. 5	2	[d]0.466	0.333
Crop reporting dist. 6	1	0.823	-
Crop reporting dist. 7	3	[c]0.570	0.169
Crop reporting dist. 9	3	[c]0.818	0.078
Key partition 21	1	0.847	-
Key partition 24	4	[c]0.857	0.030
Key partition 25	3	[b]0.666	0.210
Key partition 26	6	[c]0.614	0.148
Key partition 27	1	0.702	-
Key partition 29	3	[b]0.321	0.173
Acquisition date[e] 140	1	0.212	-
Acquisition date[e] 150	3	[b]0.467	0.251
Acquisition date[e] 170	8	[c]0.750	0.197
Acquisition date[e] 190	6	[c]0.616	0.202
Agrophysical unit 19	6	[c]0.581	0.306
Agrophysical unit 20	4	[c]0.751	0.214
Agrophysical unit 21	8	[c]0.636	0.131
Overall	18	[c]0.646	0.218

[a]Average performance = $\left\{[Pr(AI = SG/GT = SG) + Pr(AI = N/GT = N)] - K\right\} - K$

where $K = Pr(SG_{GT})Pr(SG_{AI}) + Pr(N_{GT})Pr(N_{AI})$

[b]The average performance was significantly different from random chance at the 5-percent level.

[c]The average performance was significantly different from random chance at the 1-percent level.

[d]The average performance was not significantly different from random chance at the 5-percent level.

[e]Acquisition dates are given in Julian days.

TABLE 11.– Continued.

(b) Accuracies obtained with AA tape ground truth.

Group	Sample size	Average performance (a)	Standard deviation
Crop reporting dist. 1	3	[c]0.406	0.078
Crop reporting dist. 3	4	[c]0.633	0.160
Crop reporting dist. 4	2	[d]0.487	0.233
Crop reporting dist. 5	2	[d]0.453	0.486
Crop reporting dist. 6	1	0.760	–
Crop reporting dist. 7	3	[c]0.417	0.051
Crop reporting dist. 9	3	[c]0.716	0.130
Key partition 21	1	0.773	–
Key partition 24	4	[c]0.727	0.084
Key partition 25	3	[b]0.662	0.213
Key partition 26	6	[c]0.465	0.125
Key partition 27	1	0.452	–
Key partition 29	3	[b]0.292	0.171
Acquisition date[e] 140	1	0.316	–
Acquisition date[e] 150	3	[d]0.364	0.233
Acquisition date[e] 170	8	[c]0.642	0.195
Acquisition date[e] 190	6	[c]0.518	0.174
Agrophysical unit 19	6	[c]0.530	0.283
Agrophysical unit 20	4	[c]0.641	0.171
Agrophysical unit 21	8	[c]0.505	0.158
Overall	18	[c]0.544	0.205

[a]Average performance = $\frac{[Pr(AI = W/GT = W) + Pr(AI = N/GT = N)] - K}{1 - K}$

where $K = Pr(W_{GT})Pr(W_{AI}) + Pr(N_{GT})Pr(N_{AI})$

[b]The average performance is significantly different from random chance at the 5-percent level.

[c]The average performance is significantly different from random chance at the 1-percent level.

[d]The average performance was not significantly different from random chance at the 5-percent level.

[e]Acquisition dates are given in 10-day increments.

TABLE 11.– Continued.

(c) Accuracies obtained in discriminating wheat from nonwheat using analyst ground truth.

Group	Sample size	Average performance (a)	Standard deviation
Crop reporting dist. 1	3	[c]0.412	0.137
Crop reporting dist. 3	4	[c]0.481	0.165
Crop reporting dist. 4	2	[d]0.552	0.316
Crop reporting dist. 5	2	[d]0.366	0.361
Crop reporting dist. 6	1	0.512	–
Crop reporting dist. 7	3	[b]0.433	0.167
Crop reporting dist. 9	3	[c]0.516	0.102
Key partition 21	1	0.593	–
Key partition 24	4	[c]0.440	0.151
Key partition 25	3	[c]0.566	0.079
Key partition 26	6	[c]0.493	0.188
Key partition 27	1	0.568	–
Key partition 29	3	[b]0.260	0.131
Acquisition date[e] 140	1	0.309	–
Acquisition date[e] 150	3	[d]0.422	0.271
Acquisition date[e] 170	8	[c]0.425	0.142
Acquisition date[e] 190	6	[c]0.563	0.137
Agrophysical unit 19	6	[c]0.393	0.172
Agrophysical unit 20	4	[c]0.462	0.170
Agrophysical unit 21	8	[c]0.518	0.167
Overall	18	[c]0.464	0.169

[a]Average performance = $\frac{[Pr(AI = W/GT = W) + Pr(AI = \phi/GT = \phi)] - K}{1 - K}$

where $K = Pr(W_{GT})Pr(W_{AI}) + Pr(\phi_{GT})Pr(\phi_{AI})$

[b]The average performance is significantly different from random chance at the 5-percent level.

[c]The average performance is significantly different from random chance at the 1-percent level.

[d]The average performance was not significantly different from random chance at the 5-percent level.

[e]Acquisition dates are given in 10-day increments.

TABLE 11.— Concluded.

(d) Accuracies obtained in discriminating wheat from nonwheat using AA tape ground truth.

Group	Sample size	Average performance (a)	Standard deviation
Crop reporting dist. 1	3	[c]0.320	0.025
Crop reporting dist. 3	4	[c]0.386	0.128
Crop reporting dist. 4	2	[d]0.409	0.255
Crop reporting dist. 5	2	[d]0.425	0.539
Crop reporting dist. 6	1	0.429	—
Crop reporting dist. 7	3	[d]0.184	0.110
Crop reporting dist. 9	3	[b]0.505	0.135
Key partition 21	1	0.661	—
Key partition 24	4	[c]0.366	0.107
Key partition 25	3	[b]0.577	0.204
Key partition 26	6	[c]0.301	0.185
Key partition 27	1	0.341	—
Key partition 29	3	[d]0.221	0.155
Acquisition date[e] 140	1	0.328	—
Acquisition date[e] 150	3	[d]0.330	0.250
Acquisition date[e] 170	8	[c]0.367	0.161
Acquisition date[e] 190	6	[c]0.402	0.255
Agrophysical unit 19	6	[c]0.362	0.202
Agrophysical unit 20	4	[c]0.386	0.128
Agrophysical unit 21	8	[c]0.369	0.236
Overall	18	[c]0.370	0.195

[a]Average performance = $\frac{[Pr(AI = W/GT = W) + Pr(AI = N/GT = N)] - K}{1 - K}$

where $K = Pr(W_{GT})Pr(W_{AI}) + Pr(N_{GT})Pr(N_{AI})$

[b]The average performance is significantly idfferent from random chance at the 5-percent level.

[c]The average performance is significantly different from random chance at the 1-percent level.

[d]The average performance was not significantly different from random chance at the 5-percent level.

[e]Acquisition dates are given in 10-day increments.

TABLE 12.— DIRECT WHEAT EVALUATION RESULTS OF WHEAT AND SMALL GRAINS' PROPORTION ESTIMATES

Group	Sample size	% SW (a)	% SW (b)	% SW_{GT} (c)	% SG_{GT} (d)
Crop reporting dist. 1	3	22.03	26.67	30.17	49.13
Crop reporting dist. 3	4	44.10	52.88	34.64	56.25
Crop reporting dist. 4	2	12.75	17.10	17.53	22.94
Crop reporting dist. 5	2	16.35	19.40	19.81	24.99
Crop reporting dist. 6	1	40.20	52.20	31.70	48.82
Crop reporting dist. 7	3	18.43	25.93	31.13	37.08
Crop reporting dist. 9	3	26.67	33.57	24.75	37.04
Key partition 21	1	20.80	30.30	16.63	29.59
Key partition 24	4	39.22	49.15	33.34	52.44
Key partition 25	3	38.63	45.10	31.86	49.47
Key partition 26	6	18.18	24.17	25.67	31.45
Key partition 27	1	23.90	26.00	37.70	65.99
Key partition 29	3	16.53	[f]20.67	21.93	32.32
Acquisition date[e] 140	1	28.60	35.00	28.37	50.28
Acquisition date[e] 150	3	27.93	31.87	25.33	37.64
Acquisition date[e] 170	8	31.98	41.45	28.16	43.25
Acquisition date[e] 190	6	[f]17.98	[f]22.17	28.91	38.38
Agrophysical unit 19	6	25.52	32.40	24.27	37.26
Agrophysical unit 20	4	41.20	49.75	34.78	56.68
Agrophysical unit 21	8	[f]19.79	25.22	27.30	36.14
Overall	18	[g]24.46	[h]33.07	27.95	41.08

[a]%SW = spring wheat proportion estimate.
[b]%SG = small-grains' proportion estimate.
[c]$\%SW_{GT}$ = spring wheat tape ground-truth proportion.
[d]$\%SG_{GT}$ = small grains' tape ground-truth proportion.
[e]Acquisition dates are given in 10-day increments.
[f]The wheat proportion estimate is significantly different from ground truth at the 5-percent level.
[g]The wheat proportion estimate is not significantly different from ground truth at the 5-percent level.
[h]The wheat proportion estimate is significantly different from ground truth at the 1-percent level.

The analyst labeling (spring wheat, barley, oats) of machine-classified pixels resulted in an 8-percent understatement of the small grains proportion. The LACIE PHASE III CAMS spring wheat proportions did not vary significantly from the spring wheat ground-truth proportions. The spring wheat estimate was calculated as

$$\hat{P}_{SW} = \hat{r}_{SW/SG} \cdot \hat{P}_{SG}$$

where

$\hat{P}_{SW}$ = spring wheat estimate

$\hat{r}_{SW/SG}$ = estimate of the ratio of spring wheat to total small grains

$\hat{P}_{SG}$ = BCE for small grains

The evaluation results show that $\hat{r}_{SW/SG}$ was overstated, $\hat{P}_{SG}$ was understated, and $\hat{P}_{SW}$ was nearly correct.

The statistical analysis illustrated that additional research was needed to improve correct labeling of individual spring wheat pixels, even though the overall spring wheat estimate did not vary significantly from the ground-truth proportions. A study incorporating ground-truth information and Landsat data was outlined to refine the LACIE Phase III direct wheat procedure.

4. LANDSAT IMAGERY AND SPECTRAL DATA USING GROUND-TRUTH LABELS

The following is a description of the Landsat imagery and the spectral data studied and how these data were evaluated. Tables 13 and 14 list blind site segments in the study and the results of each evaluation.

4.1 VISUAL STUDY OF THE LANDSAT IMAGERY

LACIE Product 1 is a film product created by the production film converter (PFC) from Landsat digital values in channels 1, 2, and 4 of the multispectral scanner. Channel color assignments are blue, green, and red, respectively. This product provided the image analyst with the maximum field contrast possible in the scene. Unfortunately, contrast is sometimes achieved at the expense of consistent color depiction of spectral values (ref. 11).

Product 1 was studied to determine whether or not small grains were visually separable and, if visually separable, to determine how consistently. Barley was visually separable from wheat and oats on 6 out of 18 segments, but the crop signatures were not always consistent within the segment. Refer to appendix C for field signatures on specific acquisitions.

LACIE Product 3, a film product using channels 1, 2, and 4, was designed to preserve interchannel relationships and to provide a more consistent display of spectral signatures. In contrast to Product 1, Product 3 did not necessarily use the entire range of color for each channel (ref. 11).

This product was studied to discern separation of small grains that was not apparent on Product 1. Two out of five segments with adequate Product 3 acquisition histories showed wheat and barley to be visually separable. One segment (1640) on Julian date 7193 appeared to show more separation than Product 1 for that acquisition date.

TABLE 13.— SUMMARY OF NORTH DAKOTA BLIND SITE STUDY ON THE SEPARATION OF WHEAT FROM SMALL GRAINS

Segment no.	Product 1 (visual) analysis	Product 3 (Kraus) analysis	Scatter plots (green number vs. brightness)
1602	On Julian date 7198, barley signature separable from wheat and oats, but inconsistent. A small percentage of barley evident in the segment; wheat and oats not separable	Insufficient data[a]	Low percentage of barley; oats and spring wheat intermixed on all dates
1604	Insufficient data available	Insufficient data[a]	Insufficient acquisitions; spring grains still emerging
1606	Grains not visually separable; no distinctive, separate signature for any small grain	Insufficient data[a]	Low percentage of barley and oats; no separation between spring wheat and oats
1616	No distinctive and separate signatures for wheat and barley; inadequate acquisition history	Insufficient data[a]	Critical separation acquisitions unavailable; no separation
1619	No distinctive and separate signatures for wheat, barley, and oats; inadequate acquisition history	On Julian date 7158 barley dots visually similar to oats and spring wheat; on 7175 no difference among spring grain dots; little signature variation within spring wheat, barley, or oats	Critical separation acquisitions unavailable; no separation
1622	No visual separation apparent; inadequate acquisition history; on Julian date 7176 fields of small grains still emerging; low percentage of oats	Insufficient data[a]	Critical separation acquisitions unavailable; no separation

[a]Insufficient data because of Product 3's poor acquisition history.

TABLE 13.— Continued.

Segment no.	Product 1 (visual) analysis	Product 3 (Kraus) analysis	Scatter plots (green number vs. brightness)
1625	Julian date 7179 only possible separation date because barley is brighter than spring wheat and oats; oats browner than most spring wheat fields; only small amount of small grains; strip fields present	Insufficient data[a]	Low percentage of barley; oats and spring wheat intermixed; turning acquisition unavailable
1635	Low percentage of barley and oats; spring grains in strip/fallow fields; inadequate acquisition history; no separation apparent	Insufficient data[a]	Insufficient acquisition history; low percentage of barley and oats
1637	Inadequate acquisition history; no visual separation	Insufficient data[a]	Low percentage of barley and oats; no separation
1640	Most of the barley fields harvested on 7211; oats harvested and ripe; separation possible on 7211; no apparent separation on other dates	On 7175 little difference among small grains; on best separation date (7193), spring wheat darker than barley, barley lighter and brighter than spring wheat, and no oats separation; spring grains ripe or harvested on 7211; no separation	Most of the barley dots brighter on 7193; most of barley harvested on 7211; shaky separation
1648	Inadequate acquisition history; no visual separation among winter wheat, spring wheat, barley, and oats; most of the grains in strip/fallow fields; problems identifying spring grains	Insufficient data[a]	Almost as much winter wheat as spring grains; no separation between winter and spring grains with available acquisition

[a]Insufficient data because of Product 3's poor acquisition history.

TABLE 13.— Continued.

Segment no.	Product 1 (visual) analysis	Product 3 (Kraus) analysis	Scatter plots (green number vs. brightness)
1652	Very little barley; strip/fallow fields; oats and wheat not separable; winter wheat harvested on 7197 before spring grains	Insufficient data[a]	Low percentage of barley and oats; no separation
1661	No separation with available data; strip fields present a problem; little barley in segment; inadequate acquisition history	Insufficient data[a]	Low percentage of barley; critical separation acquisitions unavailable
1663	On 7156 barley slightly brighter with some exceptions but no oat separation apparent; on 7174 and 7193 barley, wheat, and oats not separable (all at various stages); wide variety of crops on this segment	On 7156 no difference in small grains; on 7175 barley same as spring wheat and oats — very little separation; on 7211 spring grains all ripe or harvested — no visual separation	On 7175 barley brighter; on 7193 barley brighter and less green; on 7193 possible separation date; best time probably between 7175 and 7193
1939	On 7193 barley ripe and spring wheat turning; separation possible on 7193; low percentage of oats	Insufficient data[a]	Low percentage of oats; on 7193 barley brighter and more scattered on brightness axis than spring wheat
1993	No visible separation; barley and wheat have similar signatures; low percentage of barley	Insufficient data[a]	Low percentage of barley and oats; not enough barley and oats to see separation
1913	No visible separation; oat and spring wheat fields have same signatures; low percentage of barley and oat variability in spring wheat signatures	On 7161, 7179, 7197, and 7215 no differences among spring grains; very little barley; oats with same visual signature as spring wheat	Low percentage of barley and oats; not enough oats and barley to see separation

[a]Insufficient data because of Product 3's poor acquisition history.

TABLE 13.— Concluded.

Segment no.	Product 1 (visual) analysis	Product 3 (Kraus) analysis	Scatter plots (green number vs. brightness)
1927	On 7193-7194 barley separable from wheat and oats; barley harvested; oats and spring wheat not separable; on 7157-7158 barley brighter	On 7175 no signature difference; on 7193 some but not all barley brighter and not as red as spring wheat and some barley and all oats same signature as spring wheat; on 7230 all spring grains either ripe, harvested, or plowed	Barley brighter on 7193; oats planted later than other spring grains; possible separation on 7193.

TABLE 14.– SUMMARY OF PLOT EVALUATIONS

Segment no.	Green number and brightness vs. time	Channel radiance value plots	Green number and brightness vs. crop calendar	Summary of mean plots		Ground truth of segment, %			
				Brightness	Green number	Spring wheat	Barley	Oats	Winter wheat
1602	On 7179 spring wheat and oats still emerging; no separation	Low percentage of other small grains; no separation	Adjusted Robertson scale ahead of nominal; no additional separation information provided	Barley brighter than spring wheat and oats at end of June	Barley greener; no difference in oats and spring wheat	31.3	1.6	2.8	0.2
1604	Inadequate acquisitions; pre-emergence on 7143	Inadequate acquisitions	Adjusted Robertson scale ahead of nominal; no additional separation information provided	Inadequate acquisitions	Inadequate acquisitions	28.1	5.9	16.0	
1606	Jointing and heading acquisitions unavailable; no separation	No separation	Adjusted Robertson scale ahead of nominal; no additional separation information provided	No difference	Spring wheat and oats greener than barley in mid-July	24.4	1.5	5.2	
1616	On 7158 spring grains still emerging (no separation); process last of June	No separation	Adjusted Robertson scale ahead of nominal; no additional separation information provided	No significant difference	Spring wheat greener than oats and barley in early June	37.7	27.1	1.2	.5
1619	On 7158 spring wheat still emerging; process last of June; no separation	No separation	Adjusted Robertson scale ahead of nominal; no additional separation information provided	No significant difference	No difference	41.1	2.1	1.1	.1
1622	On 7159 spring grains still emerging; process last of June; no separation; on 7176 flax not emerged	No separation	Adjusted Robertson scale ahead of nominal; no additional separation information provided	Barley and wheat brighter than oats in June	Barley and wheat greener than oats in June	31.5	14.9	1.8	

TABLE 14.– Continued.

Segment no.	Green number and brightness vs. time	Channel radiance value plots	Green number and brightness vs. crop calendar	Summary of mean plots		Ground truth of segment, %			
				Brightness	Green number	Spring wheat	Barley	Oats	Winter wheat
1625	On 7179 spring grains still emerging; no separation	Low percentage of barley; no separation between wheat and oats	Adjusted Robertson scale ahead of nominal; no additional separation information provided	No difference between wheat and oats	No difference between wheat and oats	16.5	0.4	1.8	0.1
1635	Inadequate acquisitions; on 7159 over half of spring grains not emerged	Inadequate acquisitions	Adjusted Robertson scale ahead of nominal; no additional separation information provided	Inadequate acquisitions	Inadequate acquisitions	12.4	.7	1.9	
1637	No separation; missing jointing and heading acquisitions	No separation	Adjusted Robertson scale ahead of nominal; no additional separation information provided	No difference	No difference	26.5	4.3	3.4	
1640	Process last of June – all spring grains emerged; on 7175 flax not emerged	On 7193 separation of barley from wheat and oats possible (channels 2 vs. 3 and 2 vs. 4)	Adjusted Robertson scale ahead of nominal; no additional separation information provided	No significant difference	Spring wheat greener than barley after heading	31.5	13.9	3.2	.3
1648	Process last of June; no separation between spring wheat and winter wheat	No separation	Adjusted Robertson scale ahead of nominal; no additional separation information provided	Spring wheat and oats brighter than barley	No difference	14.4	2.7	3.1	18.6
1652	Process last of June; no separation	Low percentage of barley; oats and wheat not separable	Adjusted Robertson scale ahead of nominal; no additional separation information provided	No difference	No difference	25.7	1.4	3.4	.7

TABLE 14.— Concluded.

Segment no.	Green number and brightness vs. time	Channel radiance value plots	Green number and brightness vs. crop calendar	Summary of mean plots		Ground truth of segment, %			
				Brightness	Green number	Spring wheat	Barley	Oats	Winter wheat
1661	On 7159 flax not emerged; process first half of June	Lack of acquisitions	Adjusted Robertson scale ahead of nominal; no additional separation information provided	Barley brighter than spring wheat and oats on 7159	Barley greener than spring wheat and oats on 7159	25.6	0.6	5.4	0.2
1663	Process first half of June; no separation	On 7193 separation of barley from oats and wheat possible (channels 2 vs. 3 and 2 vs. 4)	Adjusted Robertson scale ahead of nominal; no additional separation information provided	No significant difference	No significant data	32.3	14.0	3.9	
1899	Process first of June; no separation	Separation on 7193 for barley and wheat (channels 2 vs. 3 and 2 vs. 4)	Adjusted Robertson scale ahead of nominal; no additional separation information provided	Barley brighter on 7193	Wheat and barley greener than oats	28.6	30.1	.2	
1903	No separation; low percentage of spring grains; process end of June	Low percentage of barley and oats	Adjusted Robertson scale ahead of nominal; no additional separation information provided	Barley slightly brighter on 7179	Barley greener on 7179	12.1	1.2	3.9	.04
1913	Lot of variability in spring wheat temporal patterns	Low percentage of barley and oats	Adjusted Robertson scale ahead of nominal; no additional separation information provided	No difference	Spring wheat greener than oats on 7197	25.7	.9	2.4	.6
1927	Process first of June; no separation	On 7193 separation of barley from oats and wheat (channels 2 vs. 3 and 2 vs. 4)	Adjusted Robertson scale ahead of nominal; no additional separation information provided	Barley brighter than spring wheat; oats vary	Barley greener on 7158 and 7174	16.6	6.7	6.2	.4

4.2 EVALUATION OF THE SPECTRAL DATA

Various graphic representations of the Landsat spectral data and ground-truth information were analyzed to determine numeric parameters for the separation of small grains and optimal crop calendar development stage. The Wehmanen implementation of the Kauth data transformations (ref. 12) was the basis for most of the graphs generated. Time variables and raw channel data values were also evaluated. The Kauth data transformations are expressed as green number and brightness values.

4.2.1 SCATTER PLOTS (GREEN NUMBER VERSUS BRIGHTNESS)

The scatter plot was generated to observe possible differences between the small grains in Kauth space. Separation of barley and other small grains was apparent at the wheat soft dough stage for 4 of the 18 segments (segments 1640, 1663, 1899, and 1927). Refer to figures 10 to 13 for examples.

4.2.2 GREEN NUMBER AND BRIGHTNESS VERSUS TIME

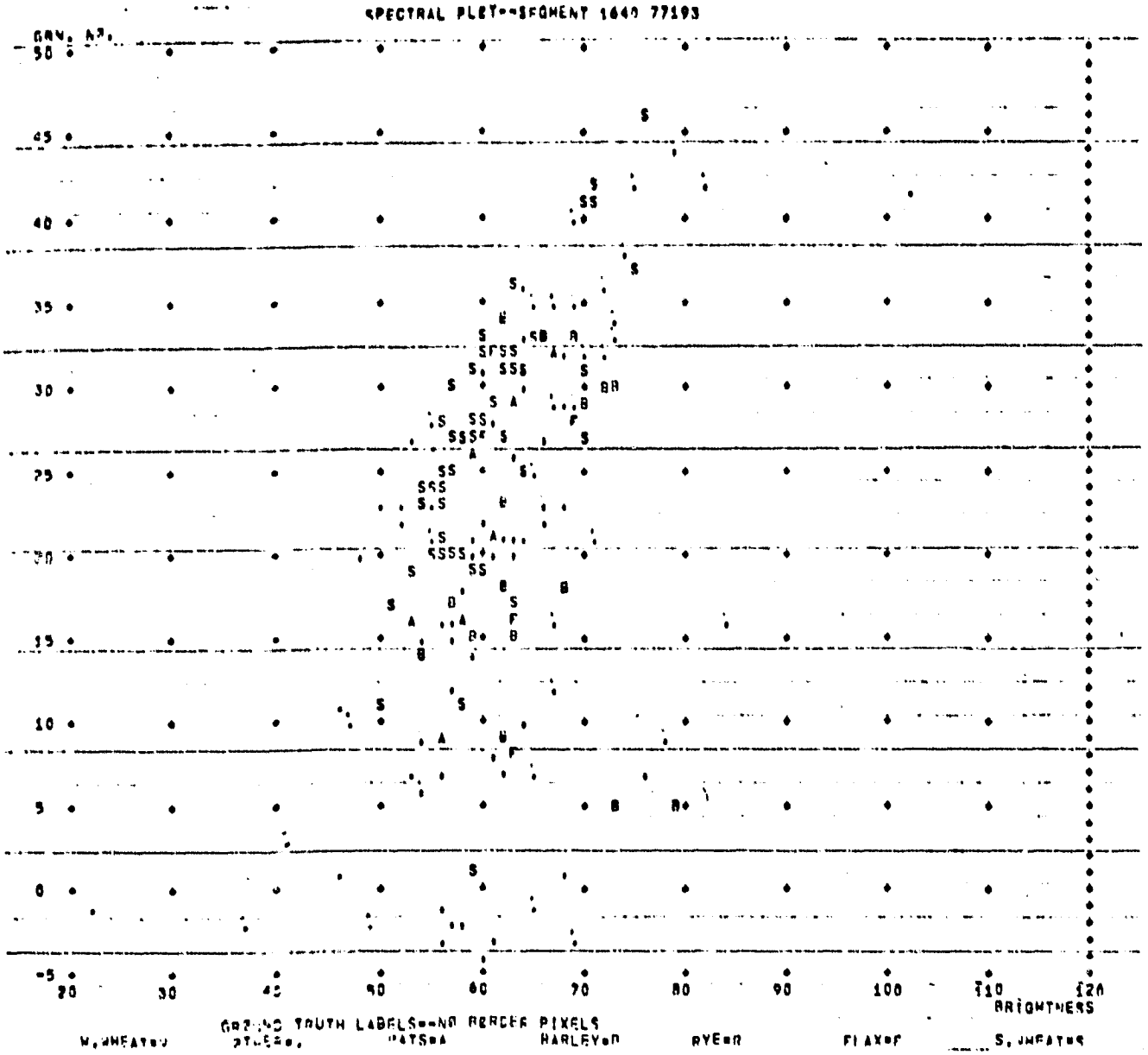
These two plots were evaluated to determine in which Kauth space and on what date separation might be apparent. No significant inputs toward separation were ascertained, but the plots clearly illustrated late emerging fields. Refer to figure 14.

4.2.3 RAW CHANNEL DATA PLOTS

These plots were studied to explore the probability that the separation of small grains is possible without data transformation. Four of 18 segments indicated separations in the channel 2 versus 3 and 2 versus 4 plots. These separations did not seem to be as well defined as the separations shown on the green number versus brightness plots. Refer to figure 15.

4.2.4 CROP CALENDAR PLOTS

Eight crop calendar plots were analyzed to determine crop calendar differences based on Kauth vectors. No additional separation information was obtained



NOTE: This scatter plot is provided for each acquisition.

Green number: Each space on the vertical axis represents one green number.

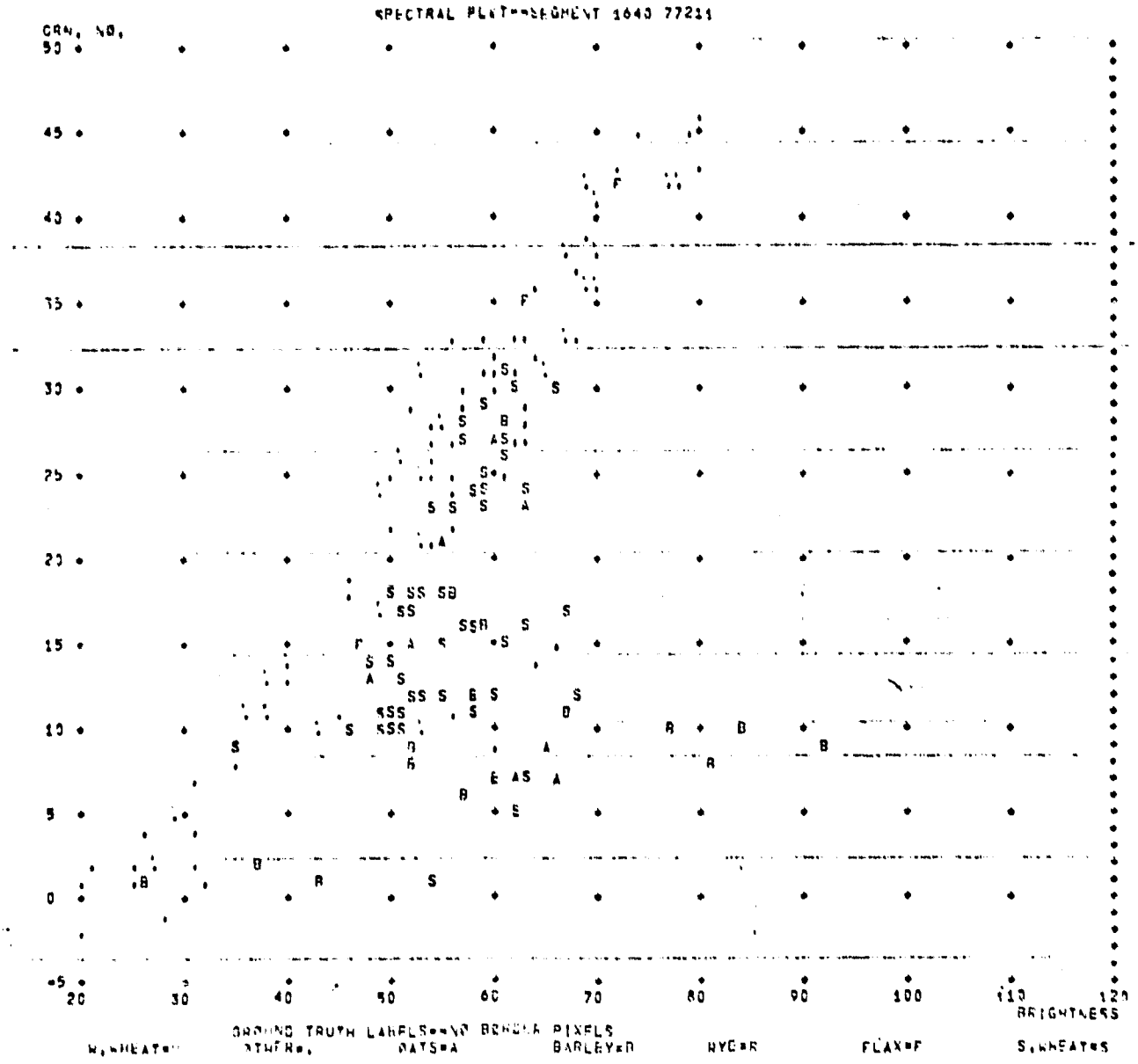
Brightness: Each space on the horizontal axis represents one brightness value.

Data representation: A data point is represented by the ground-truth symbol of the last hit.

Listings: Two listings of data were provided for each plot, one ordered by green number and one by brightness value.

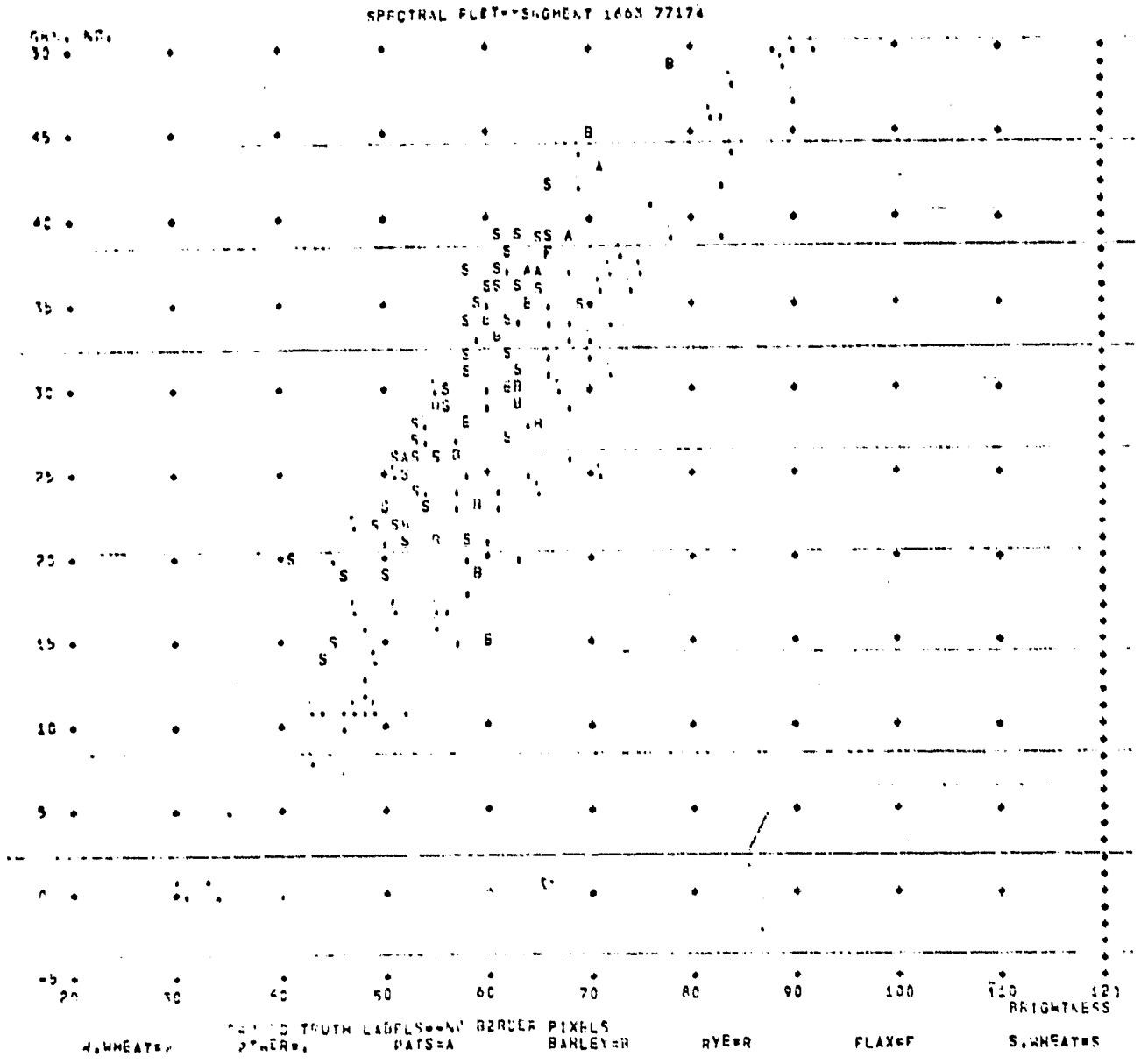
(a) Acquisition date, 77211.

Figure 10. Scatter plot for segment 1640 - green number versus brightness.



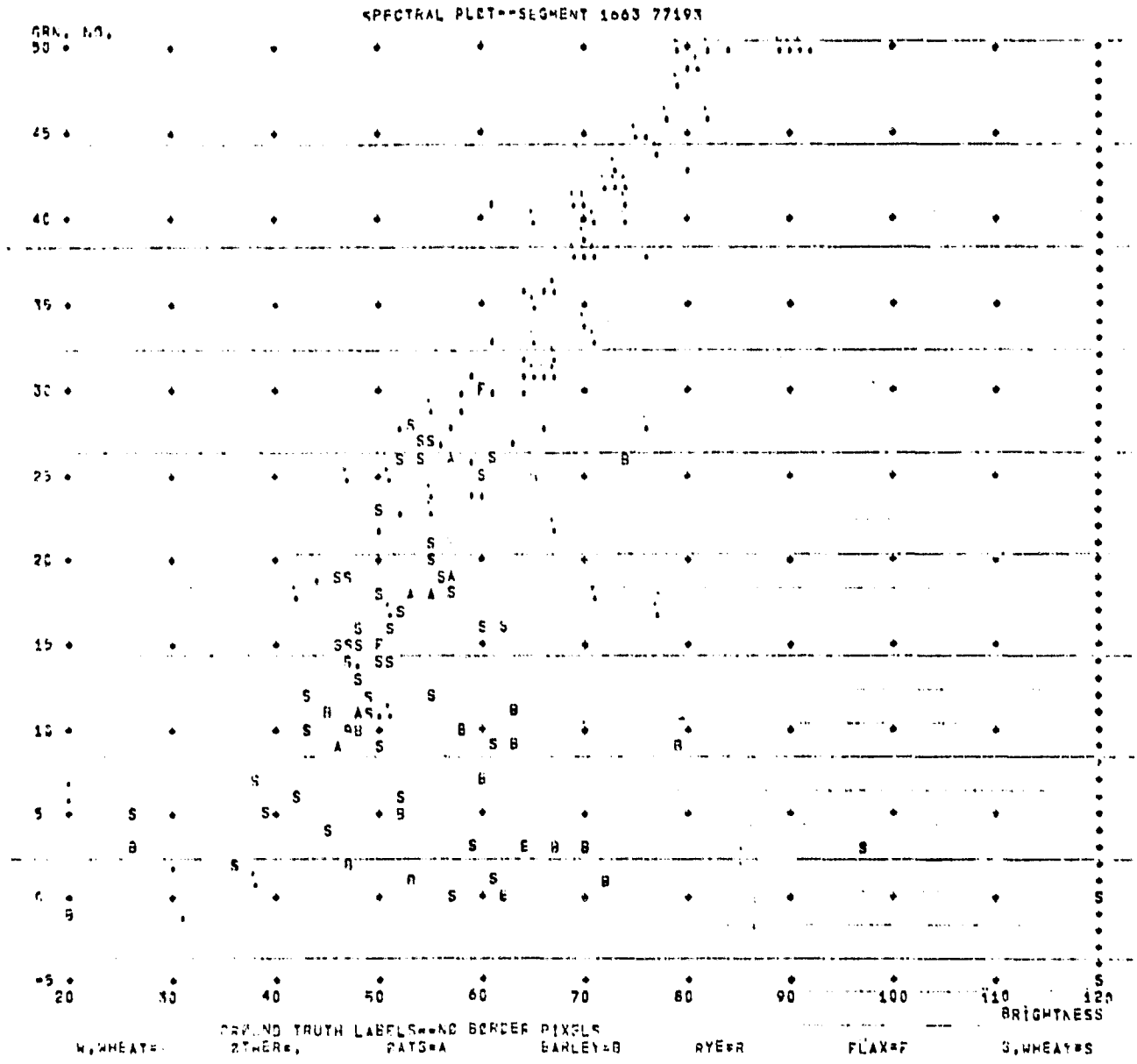
(b) Acquisition date, 77211.

Figure 10. Concluded.



(a) Acquisition date, 77174.

Figure 11.– Scatter plot for segment 1663 – green number versus brightness.



(b) Acquisition date, 77193.

Figure 11.— Concluded.

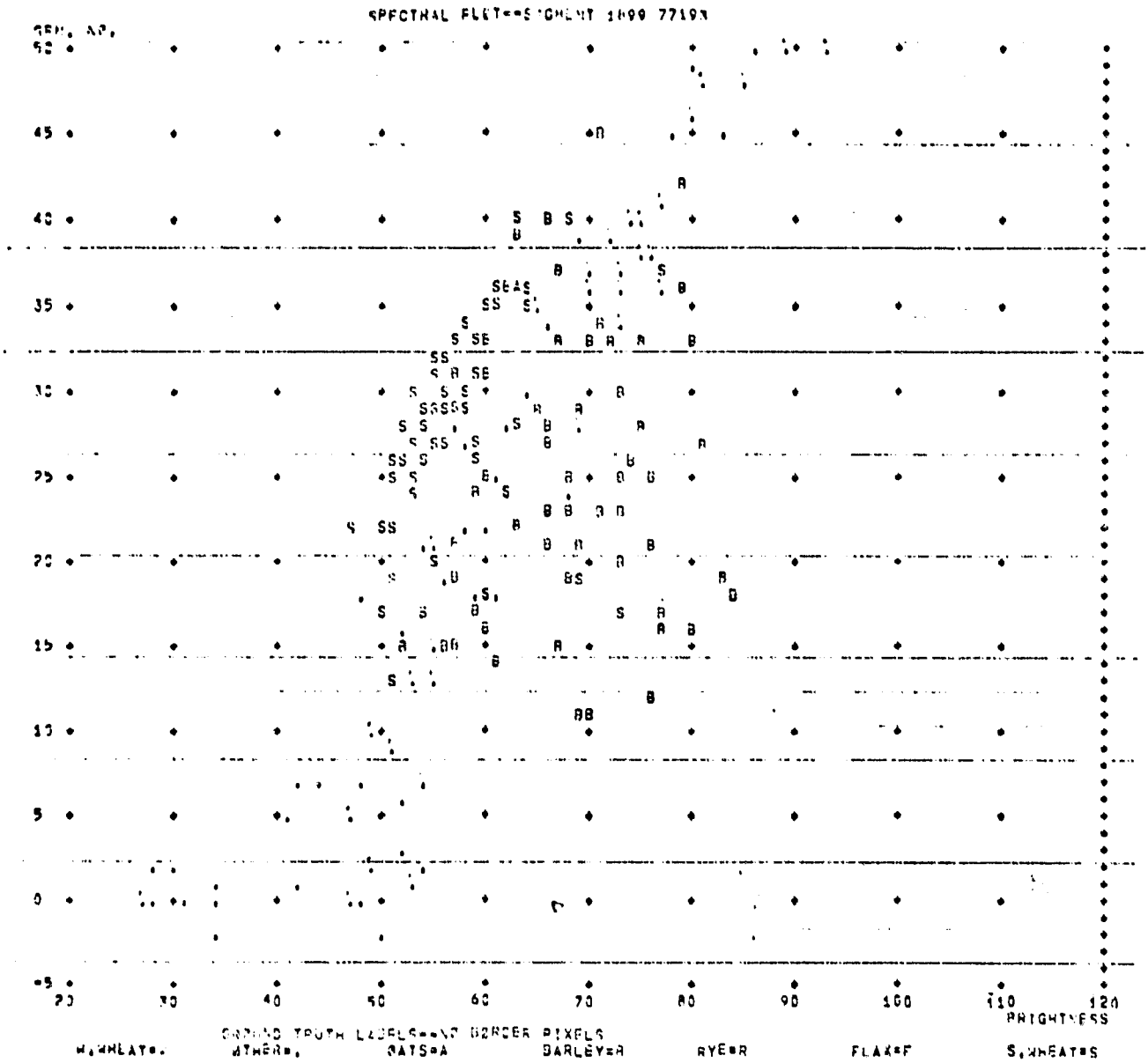


Figure 12.— Scatter plot for segment 1899 (acquisition date, 77193) — green number versus brightness.

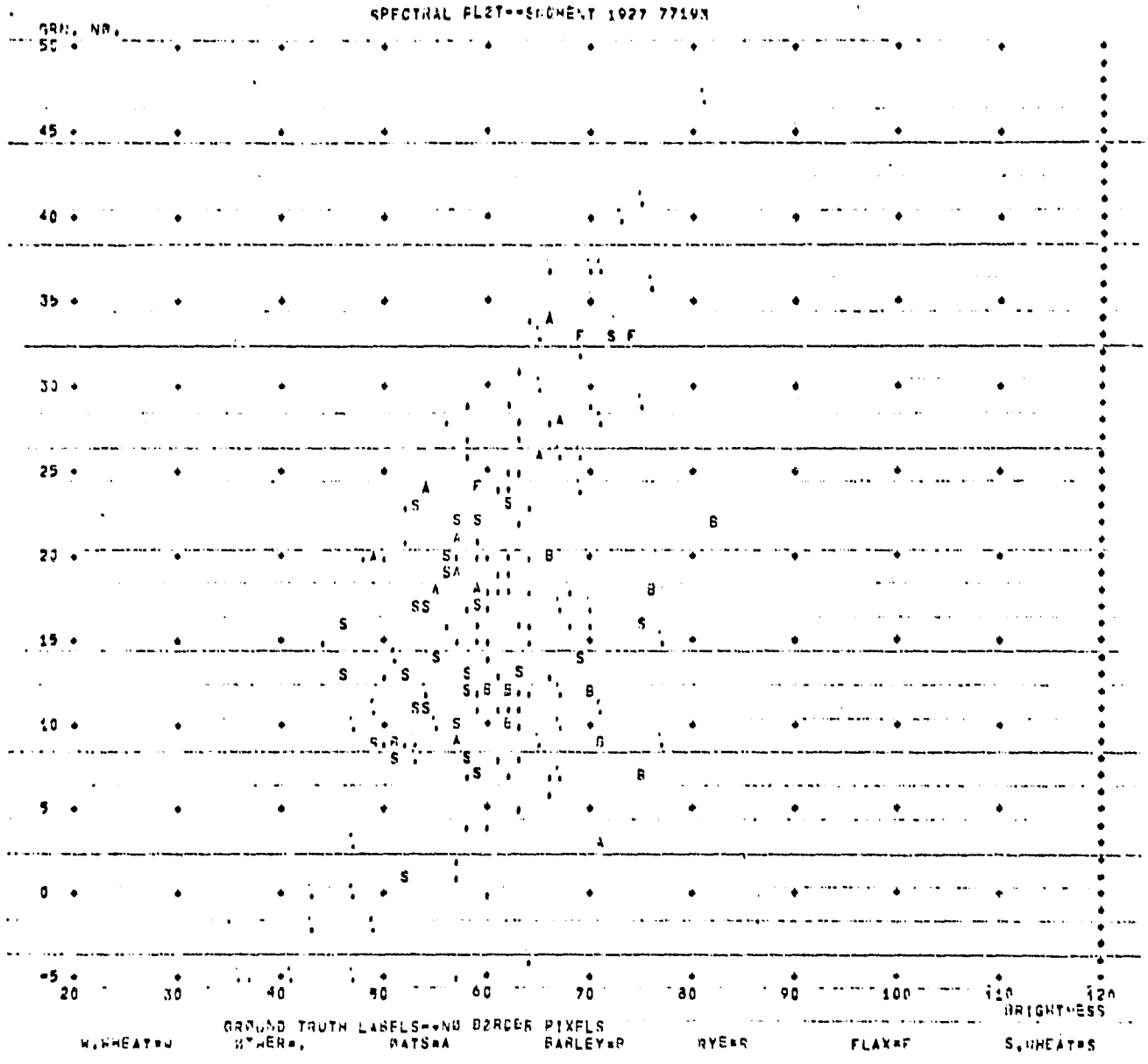
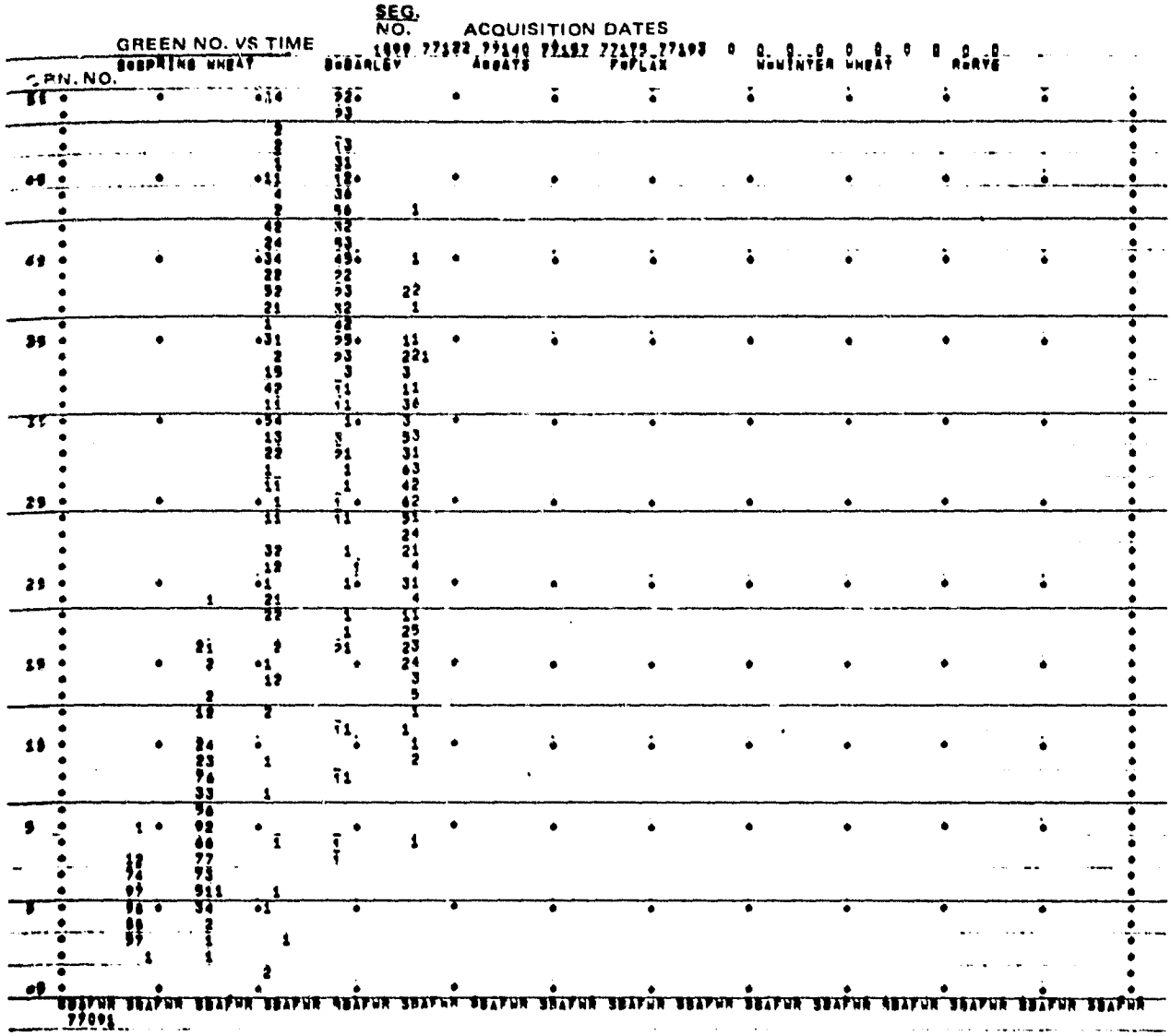


Figure 13.— Scatter plot for segment 1927 (acquisition date, 77193) — green number versus brightness.



Green number: Each space on the vertical axis represents a green number.

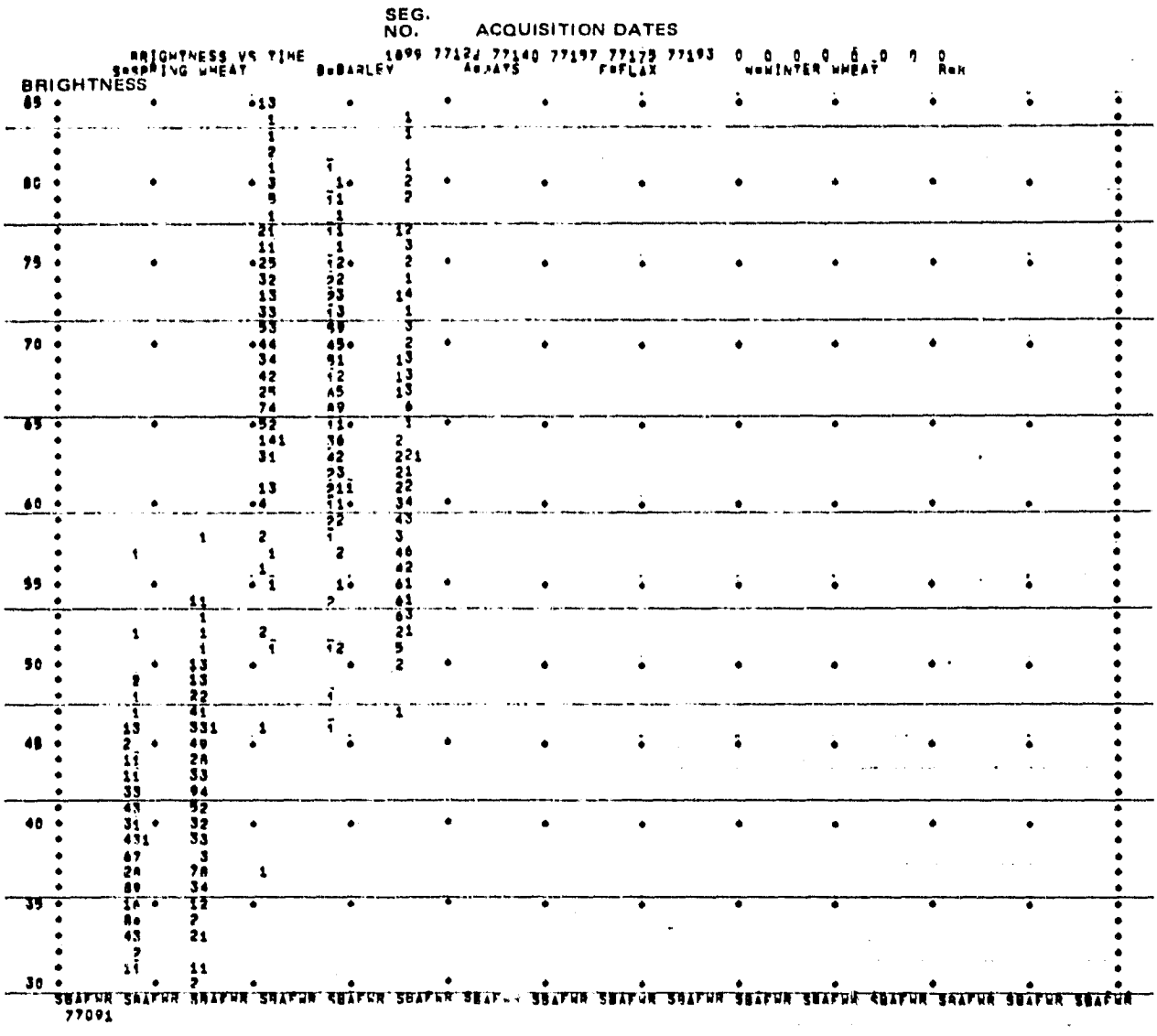
Time: Time is expressed on the horizontal axis.

Columns: There are six columns per increment in the following order (left to right): spring wheat (S), barley (B), oats (A), flax (F), winter wheat (W), and rye (R).

Data representation: The data points are represented with digits reflecting the number of hits for that point. An asterisk (*) is used for all digits over 9.

(a) Green number versus time.

Figure 14.-- Scatter plot of ground-truth data for spring wheat, barley, oats, flax, winter wheat, and rye.



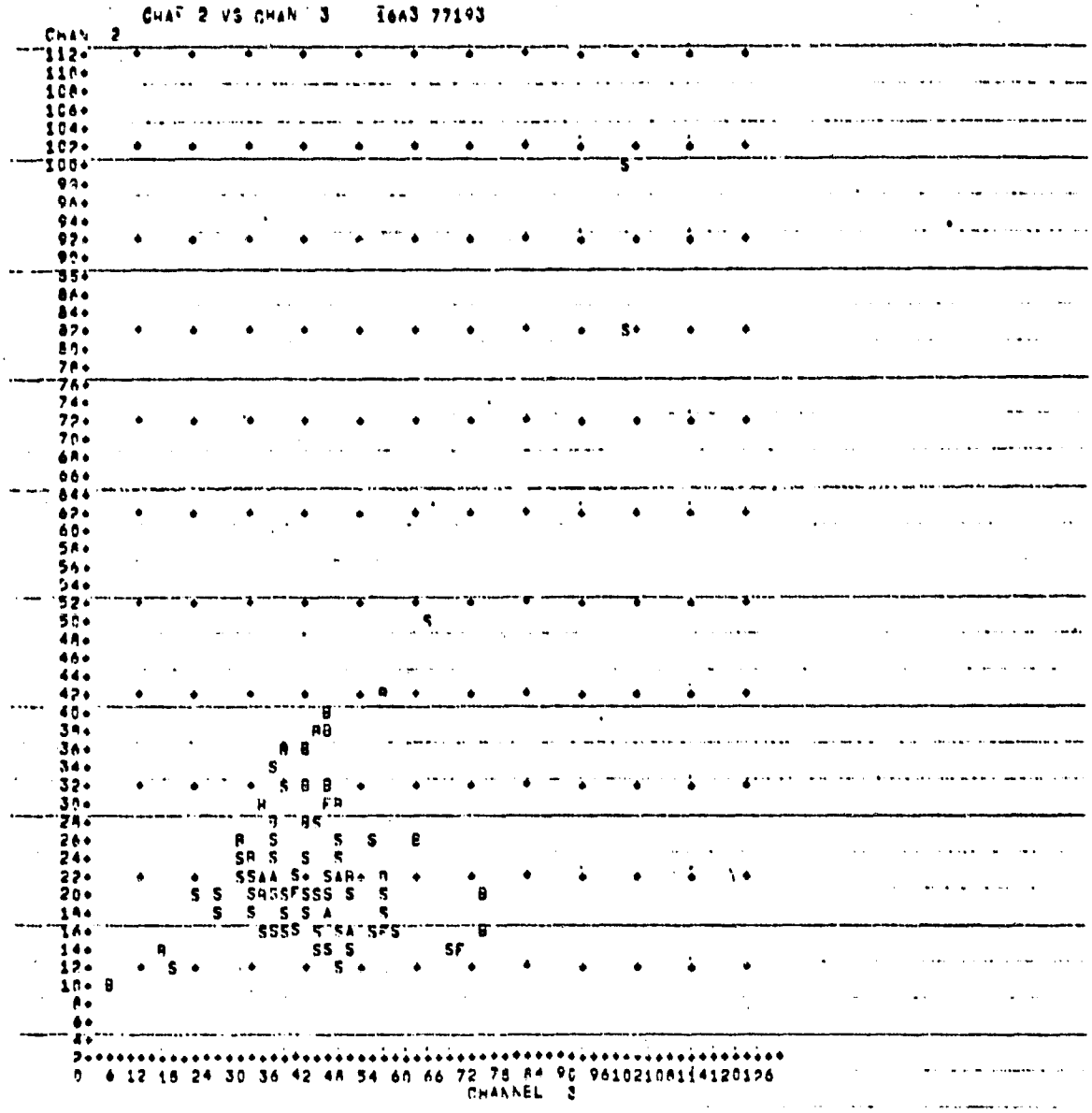
Brightness: Each space on the vertical axis represents a brightness value.

Time: Time is expressed on the horizontal axis.

Data representation: The data points are represented with digits reflecting the number of hits for that point. An asterisk (*) is used for all digits over 9.

(b) Brightness versus time.

Figure 14.— Concluded.



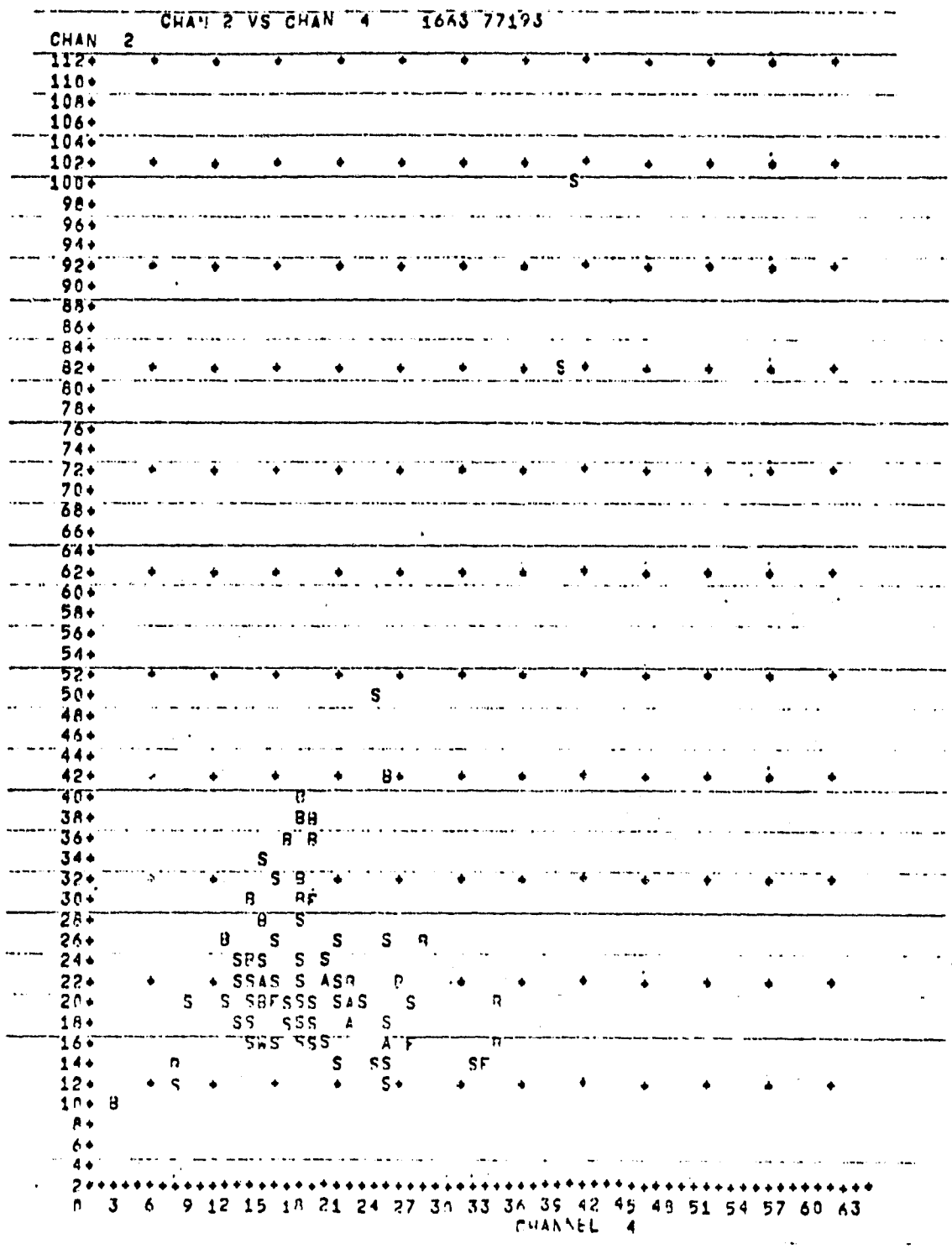
Note: This scatter plot is provided for each acquisition. Six different graphs can be plotted: Channels 1 vs. 2, 1 vs. 3, 1 vs. 4, 2 vs. 3, 2 vs. 4, and 3 vs. 4. Channels 1, 2, and 3 have a scale of 0 to 128; one space represents two radiance values. Channel 4 has a scale of 0 to 64; one space represents one radiance value.

Data representation: Data points are represented by the letter of the last hit.

Listing: A listing of multiple hits was provided for these plots.

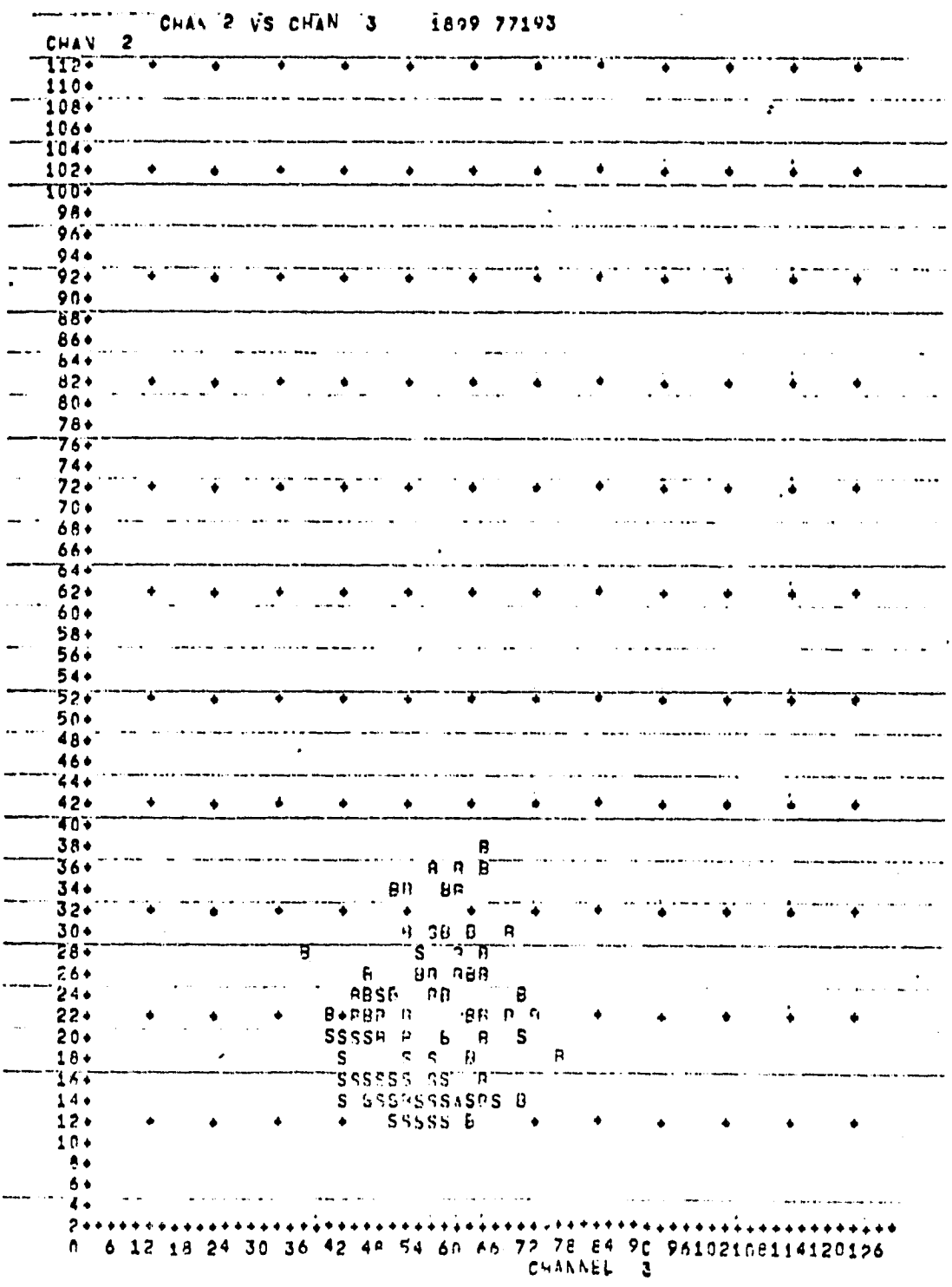
(a) Segment 1663, channel 2 versus 3.

Figure 15.— Radiance values for ground-truth labels.



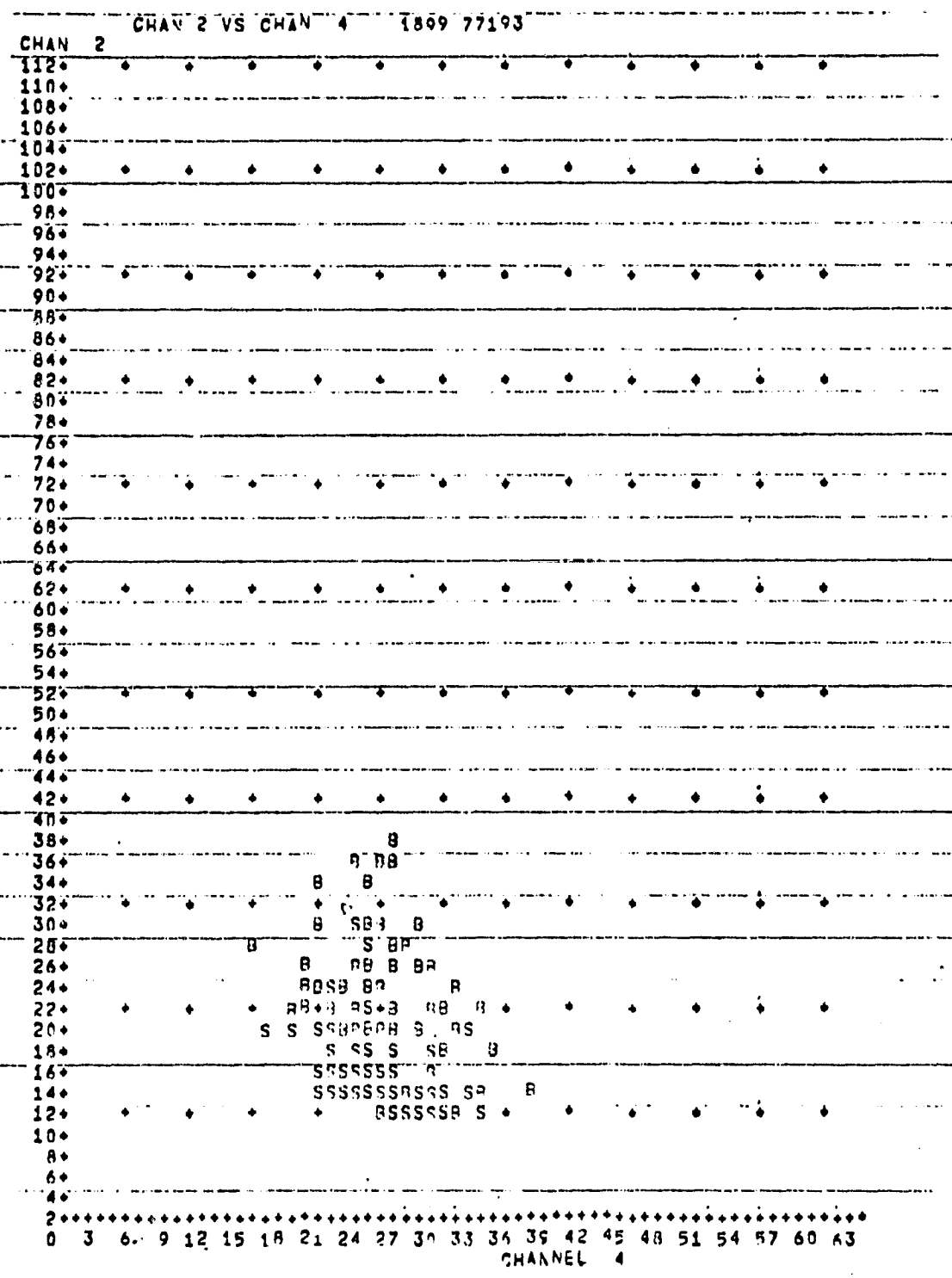
(b) Segment 1663, channel 2 versus 4.

Figure 15.— Continued.



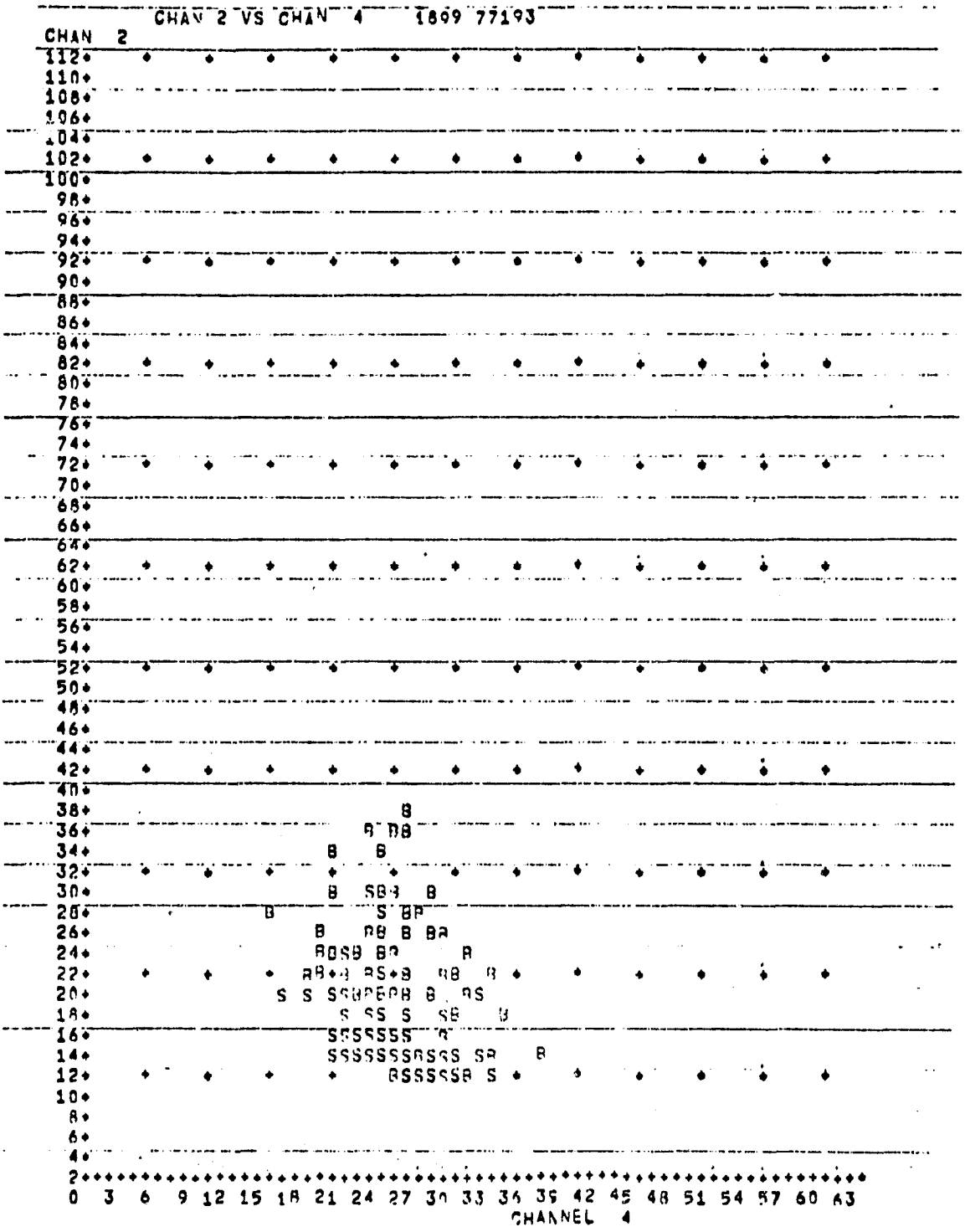
(c) Segment 1899, channel 2 versus 3.

Figure 15.– Continued.



(d) Segment 1899, channel 2 versus 4.

Figure 15.— Concluded.



(d) Segment 1899, channel 2 versus 4.

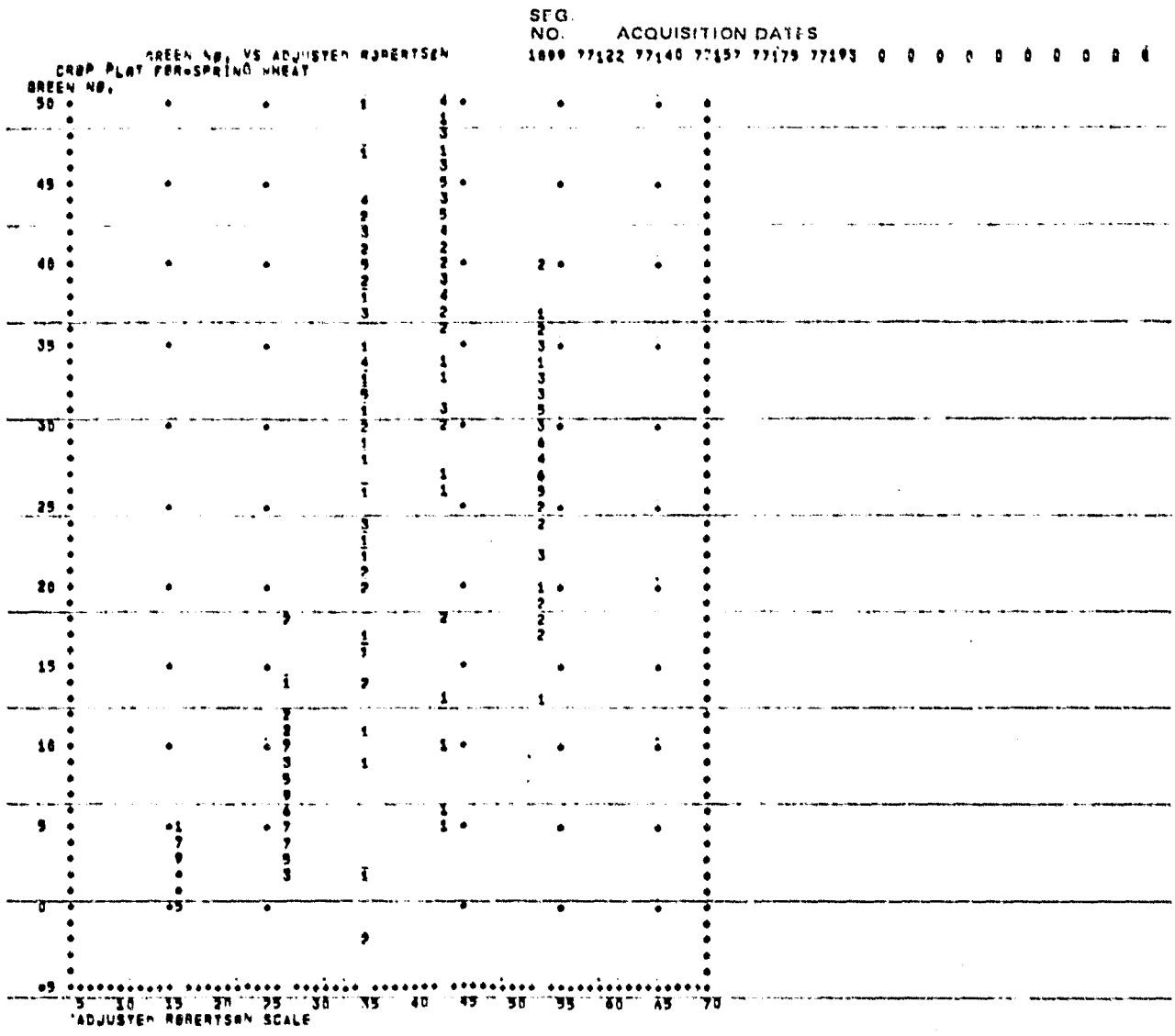
Figure 15.— Concluded.

from these graphic representations. Wheat development was assessed to be ahead of the nominal crop calendar and appeared to be consistent with the Robertson scale adjustment. Refer to figures 16 to 18.

4.2.4 MEAN AND STANDARD DEVIATION LISTINGS

Mean and standard deviation listings (see table 15) were used to derive figures 19 and 20 and to compute the 95-percent confidence limit discussed in section 5.

Study of figures 19 and 20 resulted in the basic summations stated in table 14. Generally, barley was shown to have a larger green number than wheat on four segments and a larger brightness value than wheat on five segments.



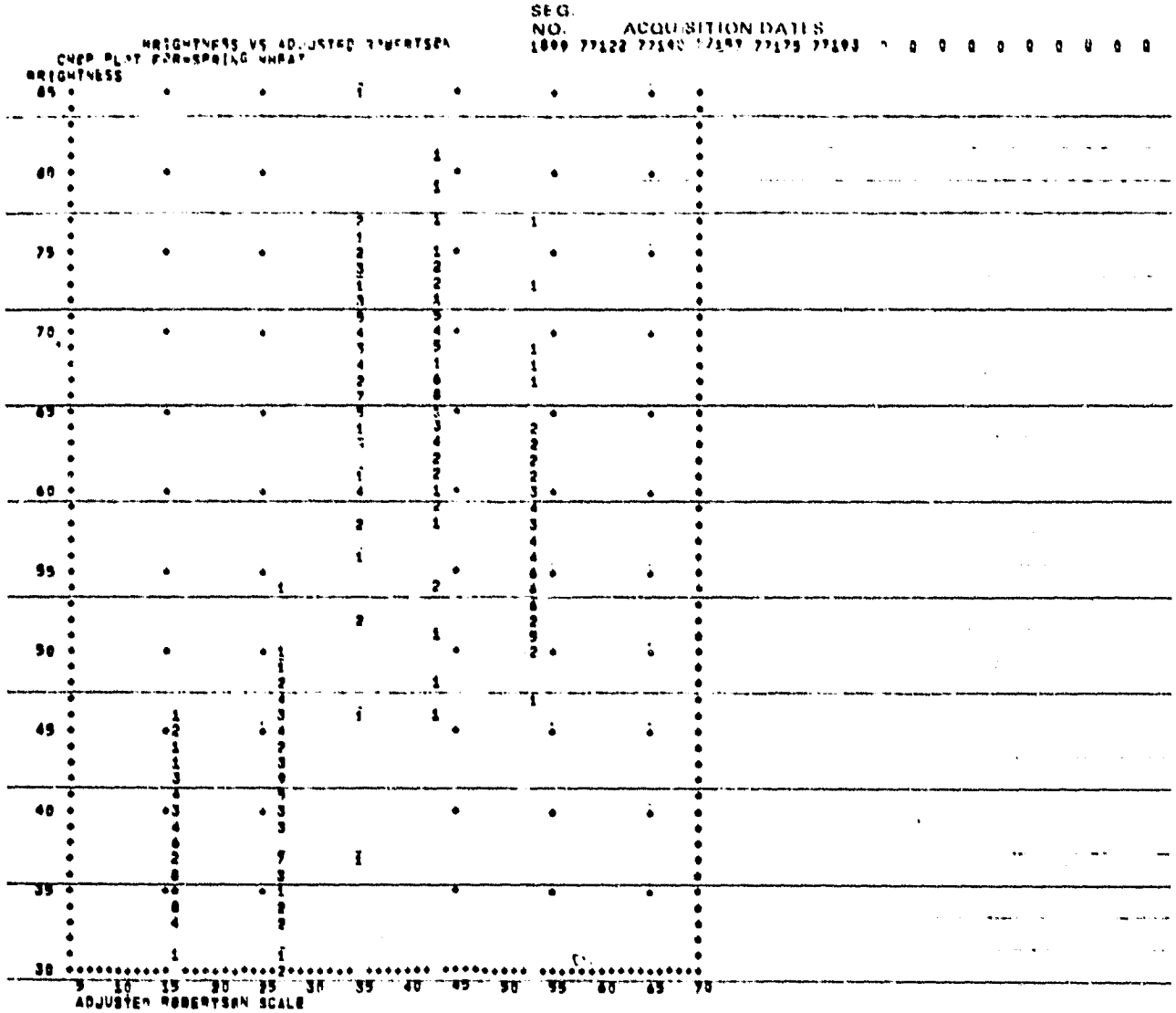
Note: Separate graphs are plotted for spring wheat, barley, oats, and flax ground-truth data.

Green number: Each space on the vertical axis represents one green number.

Robertson scale: Each space on the horizontal axis represents one-tenth.

Data representation: Data points are represented with digits reflecting the number of hits at that point. An asterisk (*) is used for all digits over 9.

Figure 16.- Green number versus adjusted Robertson scale.



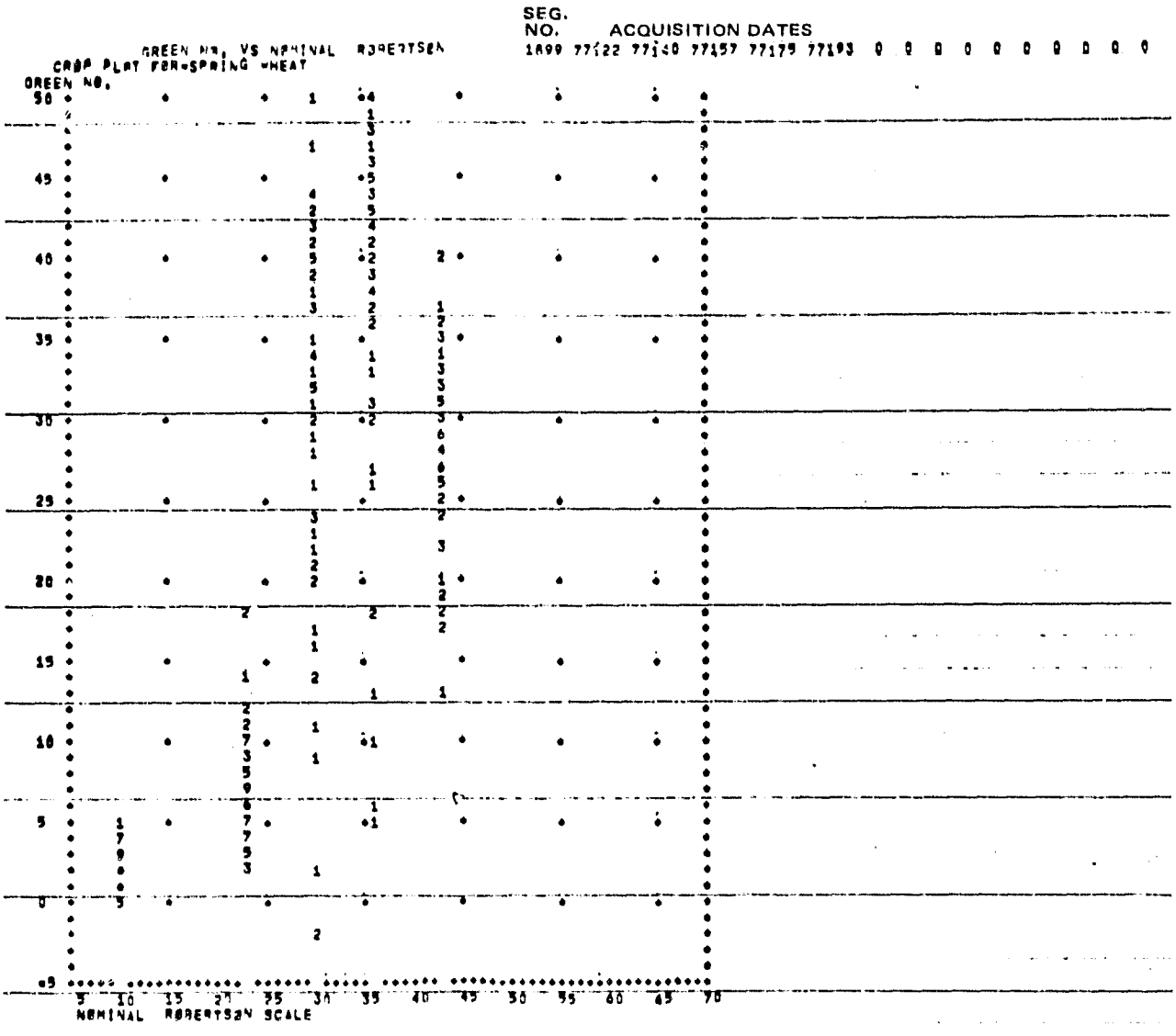
Note: Separate graphs are plotted for spring wheat, barley, oats, and flax ground-truth data.

Brightness: Each space on the vertical axis represents one brightness value.

Robertson scale: Each space on the horizontal axis represents one-tenth.

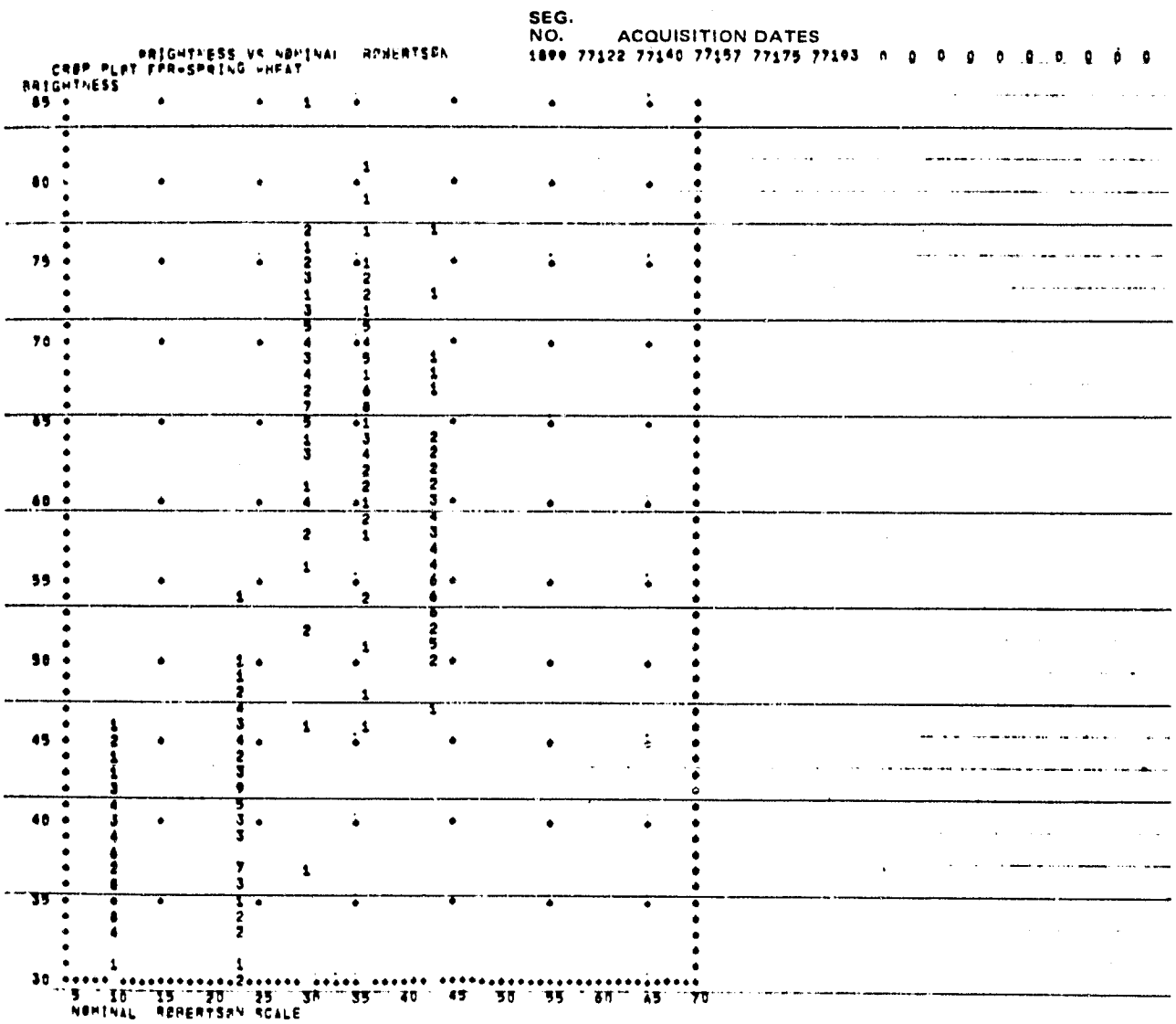
Data representation: Data points are represented with digits reflecting the number of hits at that point. An asterisk (*) is used for all digits over 9.

Figure 17.— Brightness versus adjusted Robertson scale.



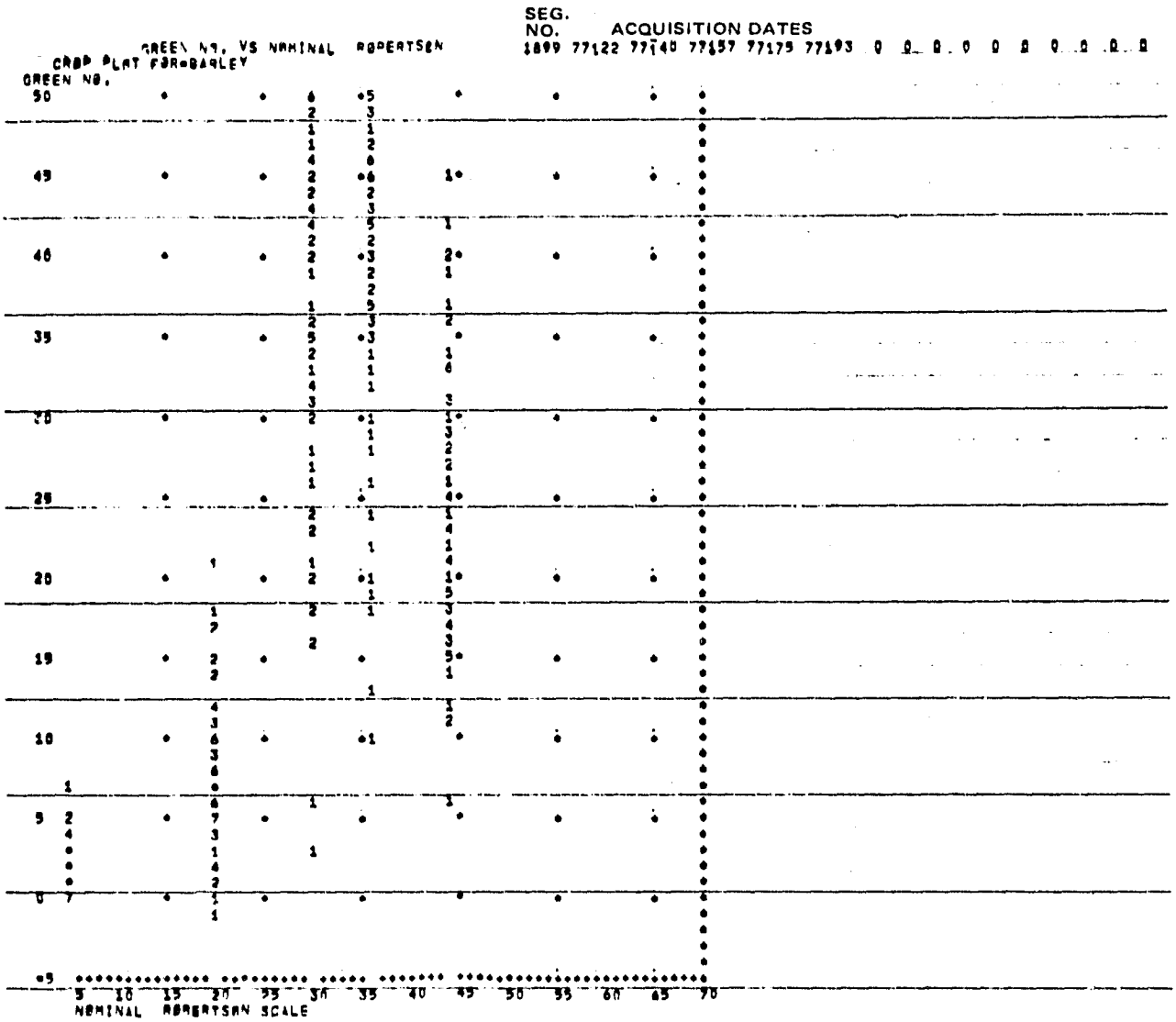
(a) Green number versus nominal Robertson scale -- crop plot for spring wheat.

Figure 18.-- Nominal crop calendar plots.



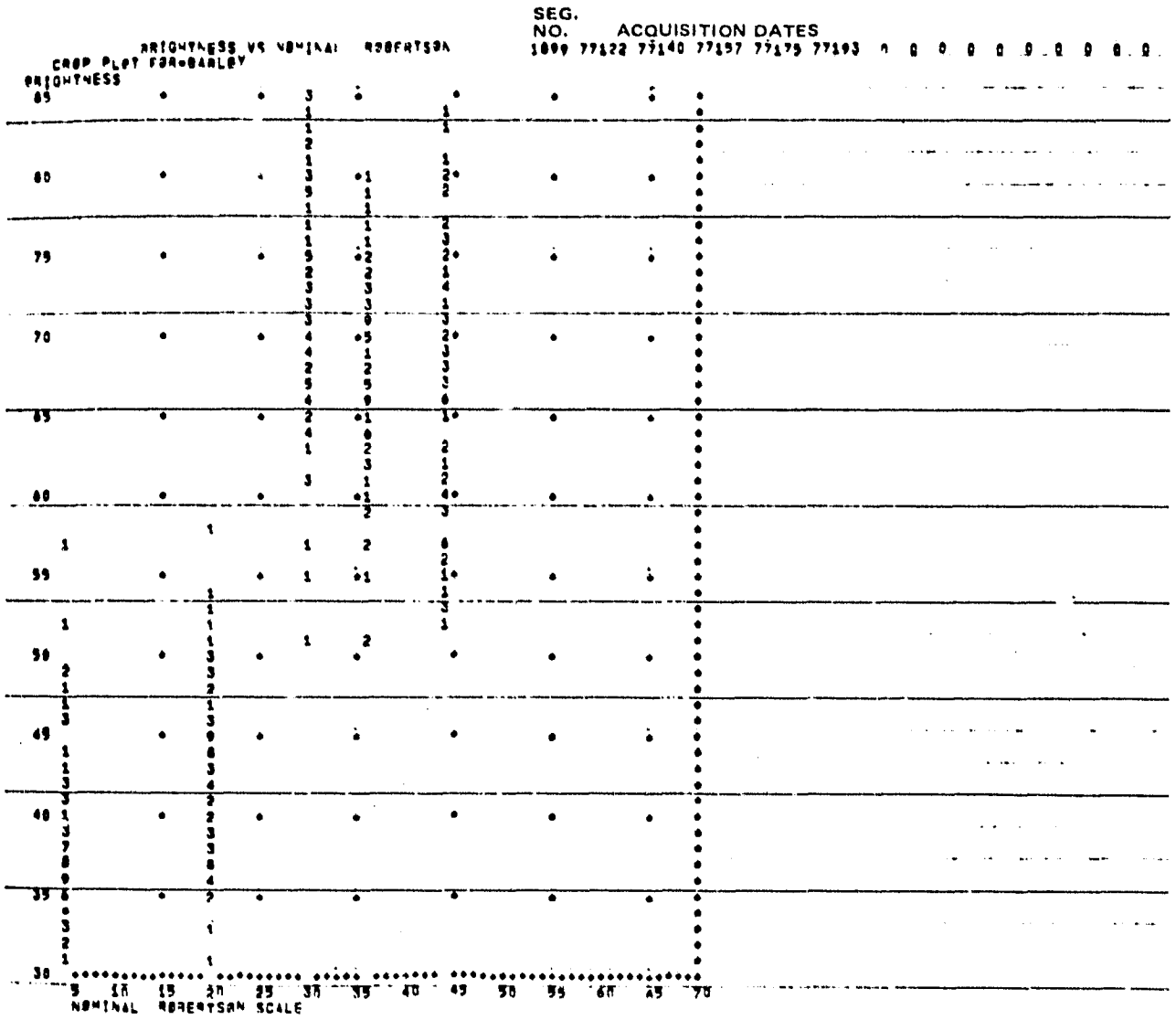
(b) Brightness versus nominal Robertson scale — crop plot for spring wheat.

Figure 18.— Continued.



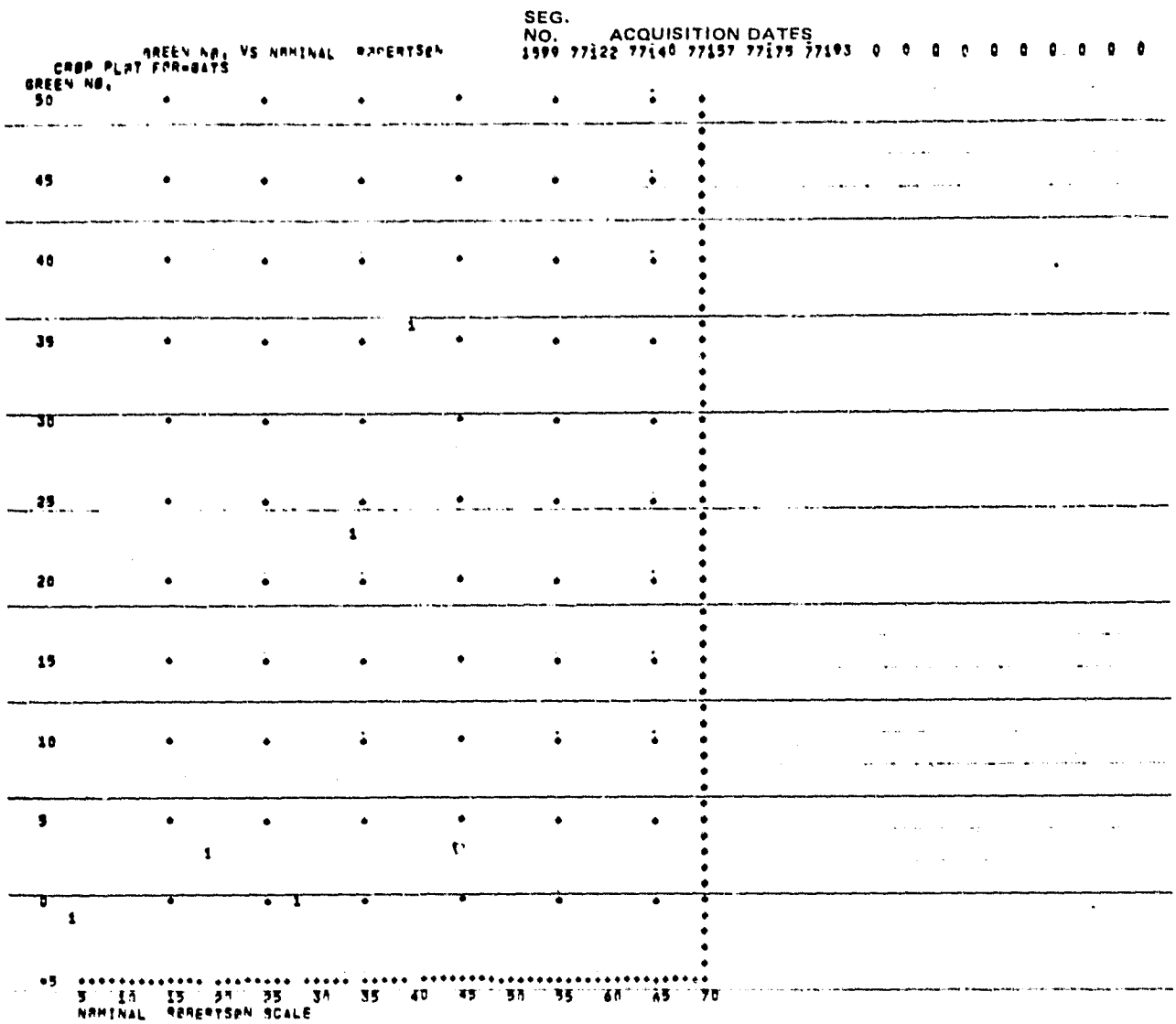
(c) Green number versus nominal Robertson scale — crop plot for barley.

Figure 18.— Continued.



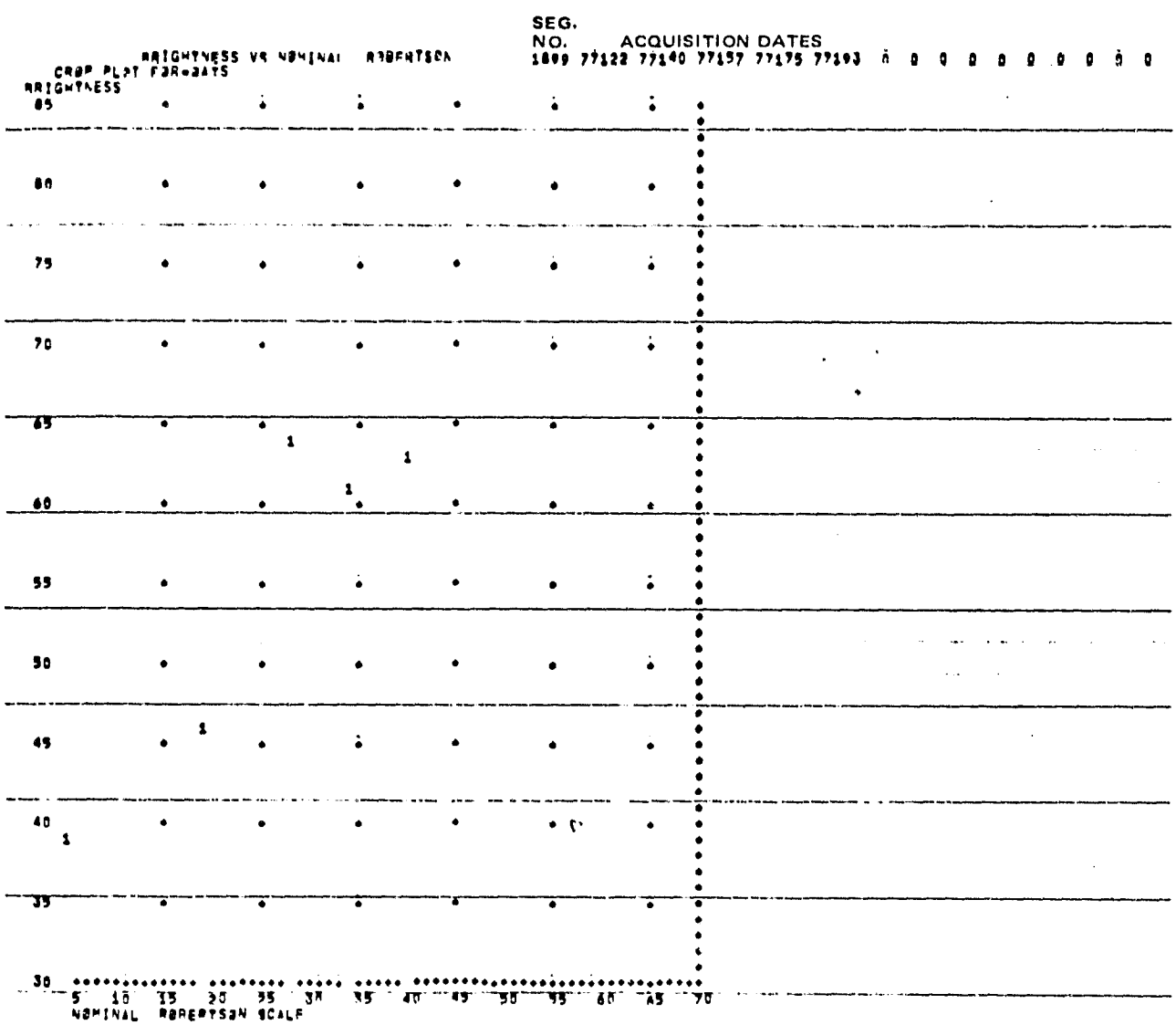
(d) Brightness versus nominal Robertson scale — crop plot for barley.

Figure 18. Continued.



(e) Green number versus nominal Robertson scale — crop plot for oats.

Figure 18.— Continued.



(f) Brightness versus nominal Robertson scale — crop plot for oats.

Figure 18.- Concluded.

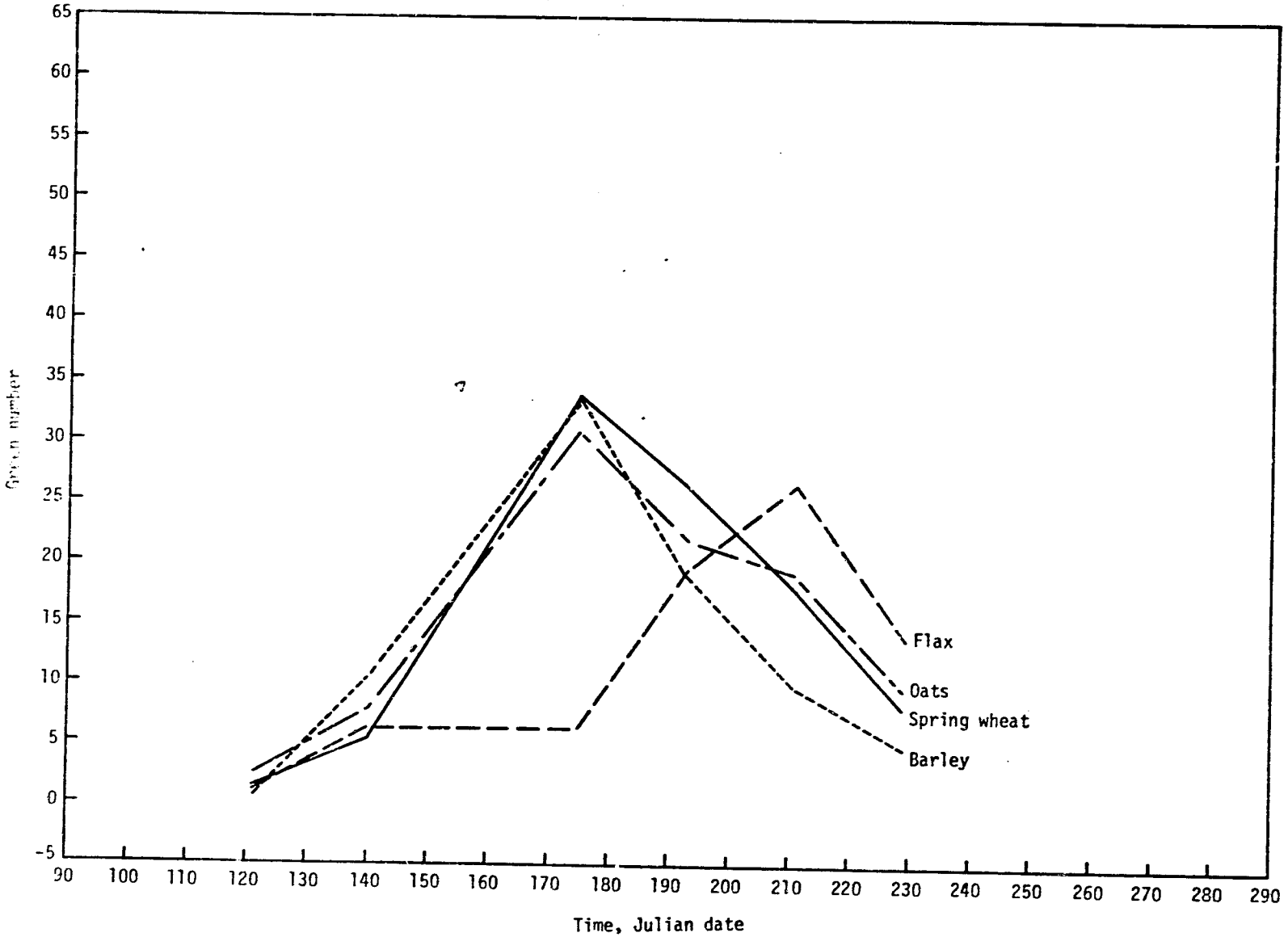


Figure 19.— Mean green number versus time (segment 1640).

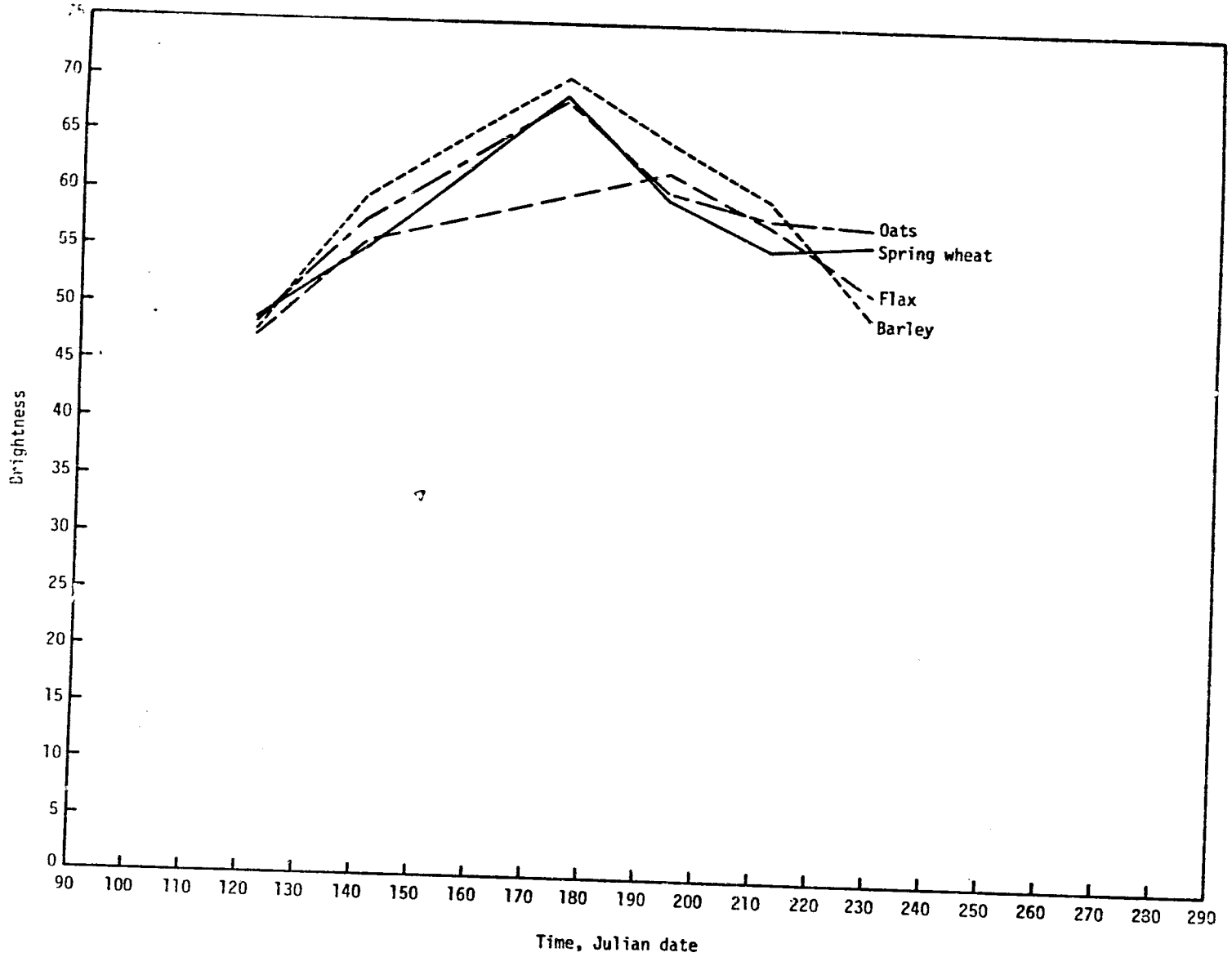


Figure 20.— Mean brightness versus time (segment 1640).

TABLE 15.— MEAN AND STANDARD DEVIATION LISTINGS

Seg.	Acq.		Wheat		Barley		Rye		Oats		Flax		Spring Wheat	
			Mean	Std. Dv.	Mean	Std. Dv.	Mean	Std. Dv.	Mean	Std. Dv.	Mean	Std. Dv.	Mean	Std. Dv.
1602	77229	BRIGHTNESS	0.0	0.0	56.7	7.5	0.0	0.0	58.4	10.7	75.3	4.9	59.7	9.6
		GREEN VAL.	0.0	0.0	3.5	1.0	0.0	0.0	4.6	2.8	0.0	1.7	4.2	2.4
		DIT CLUSTS		0.		5.		0.		11.		3.		69.
1602	77144	BRIGHTNESS	0.0	0.0	79.1	5.6	0.0	0.0	74.7	5.1	69.7	8.8	74.1	7.2
		GREEN VAL.	0.0	0.0	6.0	3.8	0.0	0.0	4.1	4.4	2.5	1.5	3.0	4.9
		DIT CLUSTS		0.		5.		0.		11.		3.		69.
1602	77179	BRIGHTNESS	0.0	0.0	79.5	7.6	0.0	0.0	60.3	16.3	60.1	31.7	67.4	17.5
		GREEN VAL.	0.0	0.0	31.7	14.6	0.0	0.0	23.9	13.2	6.8	5.7	24.1	13.4
		DIT CLUSTS		0.		5.		0.		11.		3.		69.
1602	77195	BRIGHTNESS	0.0	0.0	64.4	6.9	0.0	0.0	58.7	2.6	65.4	2.4	57.9	5.3
		GREEN VAL.	0.0	0.0	36.3	7.4	0.0	0.0	23.5	8.3	18.5	16.6	24.3	7.0
		DIT CLUSTS		0.		5.		0.		11.		3.		69.
1625	77125	BRIGHTNESS	0.0	0.0	55.5	0.0	0.0	0.0	63.4	8.0	0.0	0.0	60.2	7.1
		GREEN VAL.	0.0	0.0	4.1	0.0	0.0	0.0	5.2	7.4	0.0	0.0	1.9	3.3
		DIT CLUSTS		0.		1.		0.		14.		0.		36.
1625	77179	BRIGHTNESS	0.0	0.0	63.4	0.0	0.0	0.0	72.3	6.3	0.0	0.0	69.0	14.1
		GREEN VAL.	0.0	0.0	26.7	0.0	0.0	0.0	18.6	6.1	0.0	0.0	17.6	8.9
		DIT CLUSTS		0.		1.		0.		14.		0.		36.
1625	77233	BRIGHTNESS	0.0	0.0	85.3	0.0	0.0	0.0	71.5	7.6	0.0	0.0	73.9	10.3
		GREEN VAL.	0.0	0.0	7.5	0.0	0.0	0.0	4.3	3.7	0.0	0.0	1.7	2.4
		DIT CLUSTS		0.		1.		0.		14.		0.		36.
1637	77140	BRIGHTNESS	0.0	0.0	66.7	7.3	0.0	0.0	71.7	5.4	53.1	1.4	60.6	9.1
		GREEN VAL.	0.0	0.0	6.5	7.3	0.0	0.0	13.4	7.9	3.3	0.3	5.8	5.6
		DIT CLUSTS		0.		6.		0.		8.		2.		62.
1637	77154	BRIGHTNESS	0.0	0.0	70.2	7.3	0.0	0.0	67.8	9.6	67.9	1.6	64.1	7.7
		GREEN VAL.	0.0	0.0	25.0	10.5	0.0	0.0	22.4	3.5	33.5	3.2	26.1	7.0
		DIT CLUSTS		0.		6.		0.		8.		2.		62.
1637	77244	BRIGHTNESS	0.0	0.0	46.7	5.1	0.0	0.0	43.0	2.4	39.4	3.6	43.7	4.5
		GREEN VAL.	0.0	0.0	5.0	3.7	0.0	0.0	5.0	4.9	2.9	0.2	4.0	3.4
		DIT CLUSTS		0.		8.		0.		8.		2.		62.

5. EVIDENCE SUPPORTING SMALL-GRAIN SEPARATION

An evaluation of the 95-percent confidence limits of the true mean of wheat, barley, and oats for green number and brightness tends to support the fact that the various small grains can be separated depending on Landsat acquisition date (tables 16 and 17). It can be assumed that if the 95-percent confidence limits do not overlap or if the overlap is insignificant, it may be possible to separate the different crops. If the confidence limits are the same, separation probably would not be possible. In table 16, the green number shows only 2 of 9 possibilites at jointing and 1 of 12 at heading for possible separation. The brightness (table 17) shows wheat/barley separation on 3 of 9 at jointing, 1 of 12 at heading, 5 of 8 at soft dough, 1 of 3 at ripe, and 2 of 9 at harvest. It appears that the brightness vector contains more information for separation of the small grains than the green number vector. Acquisitions during wheat jointing and soft dough growth stages appear to provide the best opportunity for separation. Table 18 summarizes the data supporting the separation guidelines as presented in the LACIE Phase III direct wheat procedure.

TABLE 16.– 95-PERCENT CONFIDENCE LIMITS OF TRUE MEANS OF WHEAT, BARLEY, AND OATS FOR GREEN NUMBER

[Outlined boxes indicate separation possibilities.]

Segment	Grain	Sample size	Confidence limits for stages (acquisition dates), %						
			Planting (7125)	Emerging (7143)	Jointing (7158)	Heading (7179)	Soft dough (7198)	Ripe (7211)	Harvest (7230)
1602	Wheat	69	3.51, 4.69	1.59, 4.01		30.67, 36.13	23.13, 26.47		
	Barley	5	3.00, 4.79	2.60, 9.40		31.24, 47.16	23.68, 36.92		
	Oats	11	3.45, 6.35	1.03, 6.57		23.55, 37.05	21.52, 29.48		
1604	Wheat	59	1.68, 2.52	1.94, 3.86					
	Barley	17	2.21, 3.38	3.38, 8.42					
	Oats	41	1.55, 3.05	1.48, 4.72					
1606	Wheat	65		2.26, 4.34			20.09, 23.51		1.73, 3.27
	Barley	2		-4.54, 15.54			6.96, 22.24		1.62, 2.18
	Oats	9		-1.1, 4.5			16.53, 24.27		1.50, 5.10
1616	Wheat	79	-0.02, 0.62	1.52, 2.88	18.17, 23.03				4.00, 5.80
	Barley	55	-0.43, 0.43	-0.41, 1.21	11.40, 17.60				4.12, 6.88
	Oats	5	-1.25, 3.05	-3.6, 6.03	11.68, 23.12				4.25, 13.55
1613	Wheat	91	2.53, 3.07	11.61, 14.59	24.34, 34.46	34.12, 37.48			3.30, 4.90
	Barley	23	1.82, 3.58	9.66, 15.33	32.00, 40.00	30.95, 39.45			2.07, 5.33
	Oats	1	2.6	7.5	35.7	36.4			4.3
1622	Wheat	64	0.10, 0.90	5.63, 7.38	19.45, 24.15	29.20, 32.80			5.70, 7.90
	Barley	33	0.21, 1.39	3.11, 5.69	13.92, 19.07	25.39, 30.41			5.83, 10.77
	Oats	6	-1.84, 0.44	0.52, 4.28	3.36, 12.84	15.41, 24.39			5.20, 11.40
1625	Wheat	36	0.80, 3.00			14.63, 20.57			0.90, 2.50
	Barley	1	4.1			28.7			7.5
	Oats	14	1.24, 9.16			15.34, 21.86			2.32, 6.28

TABLE 16.— Continued.

Segment	Grain	Sample size	Confidence limits for stages (acquisition dates), %						
			Planting (7125)	Emerging (7143)	Jointing (7158)	Heading (7179)	Soft dough (7198)	Ripe (7211)	Harvest (7230)
1635	Wheat	35			7.34, 11.86				
	Barley	1			13.9				
	Oats	3			1.62, 22.18				
1637	Wheat	62		4.38, 7.22			24.32, 27.88		3.14, 4.86
	Barley	8		1.34, 11.66			17.58, 32.42		2.38, 7.62
	Oats	8		7.81, 18.99			19.93, 24.97		1.54, 8.46
1640	Wheat	65	0.75, 1.65	3.71, 6.89		31.59, 36.01	24.07, 27.93	15.79, 19.61	6.04, 9.56
	Barley	21	-0.16, 2.37	6.79, 14.21		29.42, 37.37	15.99, 24.20	7.89, 13.91	3.28, 9.32
	Oats	13	0.93, 4.26	4.73, 10.27		26.21, 35.19	17.79, 27.21	14.56, 23.44	4.31, 14.29
1648	Wheat	27	0.08, 1.92	-0.82, 2.02		19.16, 25.24			
	Barley	6	-0.85, 4.05	0.75, 5.65		21.92, 31.88			
	Oats	6	0.14, 5.86	-3.1, 4.54		17.98, 27.61			
1652	Wheat	70	0.86, 2.54	1.99, 4.81		22.56, 26.44	18.25, 21.35		1.45, 2.75
	Barley	3	-1.19, 1.59	-6.63, 1.23		28.47, 37.93	20.25, 23.95		-0.74, -0.25
	Oats	10	1.03, 5.97	2.97, 9.43		22.13, 35.67	16.30, 23.50		0.95, 5.25
1661	Wheat	61	1.84, 2.96		17.63, 21.37				
	Barley	1	0.6		26.4				
	Oats	11	1.53, 4.67		12.05, 23.75				
1663	Wheat	64	2.43, 4.18	9.98, 14.23	29.28, 33.13	26.85, 30.35	12.18, 16.83	4.53, 6.88	4.30, 7.70
	Barley	25	2.60, 3.80	12.78, 21.42	32.12, 38.28	25.50, 31.50	6.00, 15.20	2.96, 7.84	0.44, 9.96
	Oats	7	0.70, 1.90	5.36, 10.04	33.67, 41.53	31.32, 40.08	13.12, 21.88	4.99, 6.81	2.44, 10.16

TABLE 16.— Concluded.

Segment	Grain	Sample size	Confidence limits for stages (acquisition dates), %						
			Planting (7125)	Emerging (7143)	Jointing (7158)	Heading (7179)	Soft dough (7198)	Ripe (7211)	Harvest (7230)
1899	Wheat	59	1.68, 2.31	6.09, 7.91	27.52, 33.87	35.21, 40.99	26.49, 29.51		
	Barley	67	1.76, 2.44	6.82, 8.98	32.97, 38.63	36.77, 41.42	22.10, 26.30		
	Oats	1							
1903	Wheat	19	0.38, 2.22			21.05, 29.95	16.80, 22.40		-0.50, 1.7
	Barley	0							
	Oats	5	0.65, 3.34			6.7, 27.10	13.29, 19.91		-0.16, 3.95
1913	Wheat	43	0.41, 2.0	0.25, 2.75	8.65, 13.35	16.82, 22.98	14.43, 17.97	5.38, 7.82	
	Barley	0							
	Oats	6	0.73, 5.47	3.08, 7.32	9.83, 17.17	18.57, 29.03	6.83, 17.77	1.69, 8.71	
1927	Wheat	43	2.50, 4.70	11.64, 16.16	25.56, 33.24	25.75, 31.85	15.12, 18.48		2.70, 6.30
	Barley	10	1.98, 5.02	9.97, 21.23	29.94, 38.86	28.77, 37.63	10.86, 19.34		3.15, 8.85
	Oats	14	1.90, 4.90	5.46, 14.54	21.58, 34.62	28.54, 38.26	19.28, 27.72		2.99, 6.41

TABLE 17.— 95-PERCENT CONFIDENCE LIMITS OF TRUE MEANS OF WHEAT, BARLEY, AND OATS FOR BRIGHTNESS

[Outlined boxes indicate separation possibilities.]

Segment	Grain	Sample size	Confidence limits for stages (acquisition dates), %						
			Planting (7125)	Emerging (7143)	Jointing (7158)	Heading (7179)	Soft dough (7198)	Ripe (7211)	Harvest (7230)
1602	Wheat	69	56.71, 61.29	72.10, 75.70		66.03, 72.77	56.[illegible] 59.20		
	Barley	5	51.99, 65.41	68.09, 78.11		68.62, 82.58	58.23, 70.59		
	Oats	11	52.05, 64.95	69.76, 77.24		50.01, 69.19	57.73, 60.87		
1604	Wheat	59	39.14, 44.46	65.88, 69.52					
	Barley	17	35.87, 47.13	66.93, 71.68					
	Oats	41	49.14, 57.26	69.66, 73.54					
1606	Wheat	65		66.22, 71.38			53.93, 55.67		43.26, 45.94
	Barley	2		71.50, 74.90			49.18, 56.82		32.55, 50.65
	Oats	9		64.87, 72.33			49.87, 55.73		39.37, 47.23
1616	Wheat	79	51.54, 54.46	65.82, 68.98	67.15, 69.45				63.97, 68.83
	Barley	55	52.83, 57.57	63.35, 66.85	63.15, 67.85				67.68, 75.07
	Oats	5	57.18, 63.62	63.99, 72.21	64.65, 68.95				45.97, 62.43
1619	Wheat	91	34.89, 36.91	47.59, 50.81	61.73, 65.47	61.88, 64.52			42.78, 48.82
	Barley	23	34.84, 40.76	48.03, 53.37	64.50, 70.50	61.36, 68.04			31.95, 41.45
	Oats	1	42.2	51.51	65.61	63.61			49.09
1622	Wheat	64	64.68, 68.33	55.65, 60.75	59.90, 63.50	62.50, 64.70			53.85, 57.35
	Barley	33	65.20, 70.00	52.29, 58.91	57.15, 61.25	60.80, 64.00			54.07, 60.33
	Oats	6							
1625	Wheat	36	57.83, 62.57			64.30, 73.70			69.83, 76.97
	Barley	1	55.5			63.4			85.3
	Oats	14	59.12, 67.68			68.93, 75.67			67.44, 75.56

TABLE 17.– Continued.

Segment	Grain	Sample size	Confidence limits for stages (acquisition dates), %						
			Planting (7125)	Emerging (7143)	Jointing (7158)	Heading (7179)	Soft dough (7198)	Ripe (7211)	Harvest (7230)
1635	Wheat	35			67.47, 71.53				
	Barley	1			73.9				
	Oats	3			61.08, 76.32				
1637	Wheat	62		58.29, 62.91			62.14, 66.06		42.56, 44.84
	Barley	8		55.53, 65.86			65.04, 75.36		40.09, 47.31
	Oats	8		67.88, 75.52			61.01, 74.59		41.3, 44.70
1640	Wheat	65	46.79, 50.61	53.67, 57.93		68.51, 71.09	58.54, 61.26	53.06, 56.74	53.71, 58.08
	Barley	21	45.05, 51.95	55.23, 63.17		67.53, 72.07	61.56, 67.24	57.41, 62.39	45.12, 55.08
	Oats	13	45.37, 51.03	52.99, 62.42		65.83, 70.37	58.13, 62.46	54.06, 60.94	44.56, 73.84
1648	Wheat	27	67.71, 73.49	90.97, 96.83		72.99, 79.61			
	Barley	6	65.22, 78.78	79.02, 94.38		74.71, 80.09			
	Oats	6	69.19, 84.21	85.84, 101.36		76.65, 85.95			
1652	Wheat	70	64.01, 67.79	72.31, 75.89		70.74, 74.86	60.29, 64.11		75.70, 80.10
	Barley	3	52.97, 81.83	58.16, 102.04		67.91, 82.69	56.49, 70.11		94.65, 101.35
	Oats	10	59.36, 65.44	68.08, 75.92		68.49, 78.11	57.53, 64.87		69.48, 89.72
1661	Wheat	61	50.18, 56.02		67.90, 70.10				
	Barley	1	49.2		74.5				
	Oats	11	44.67, 53.83		63.14, 70.86				
1663	Wheat	64	39.75, 43.05	61.3, 64.1	59.58, 61.82	54.88, 58.13	50.25, 61.15	48.35, 54.05	37.00, 44.4
	Barley	25	39.8, 45.4	64.2, 71.8	62.82, 68.18	57.42, 62.78	51.2, 63.6	46.64, 55.76	28.04, 40.76
	Oats	7	36.12, 43.08	56.64, 64.96	61.66, 70.74	58.74, 68.26	49.55, 56.05	62.31, 72.29	43.45, 48.75

TABLE 17.— Concluded.

Segment	Grain	Sample size	Confidence limits for stages (acquisition dates), %						
			Planting (7125)	Emerging (7143)	Jointing (7158)	Heading (7179)	Soft dough (7198)	Ripe (7211)	Harvest (7230)
1899	Wheat	59	36.39, 38.21	39.49, 42.31	64.47, 68.53	63.54, 68.65	55.62, 58.58		
	Barley	67	37.05, 39.55	41.58, 44.22	69.72, 73.48	65.93, 68.87	64.55, 68.65		
	Oats	1							
1903	Wheat	19	50.23, 57.57			47.09, 65.71	49.36, 52.84		80.83, 88.17
	Barley	0							
	Oats	5	46.77, 61.43			7.17, 74.43	44.84, 51.36		59.83, 82.37
1913	Wheat	43	64.85, 70.15	78.28, 84.32	57.00, 60.60	68.82, 74.18	56.85, 59.35	74.98, 81.81	
	Barley	0							
	Oats	6	59.81, 72.39	71.32, 92.88	55.78, 67.22	66.06, 81.74	54.91, 65.69	78.93, 91.67	
1927	Wheat	43	48.55, 53.25	52.58, 56.42	65.43, 69.57	62.65, 65.95	52.41, 58.99		48.05, 51.35
	Barley	10	47.13, 52.07	53.66, 62.14	64.10, 74.10	63.04, 68.36	63.30, 74.30		42.20, 55.60
	Oats	14	48.99, 53.81	49.62, 58.38	64.66, 72.14	64.07, 69.53	56.30, 62.50		45.20, 53.00

TABLE 18.– SUMMARY OF DATA SUPPORTING WHEAT-BARLEY SEPARATION

Data source	LACIE Phase III direct wheat procedure separation guideline					
	(a)	(b)	(c)	(d)	(e)	(f)
LACIE Phase III North Dakota blind site study		X	X	X		
Earlier separation studies (ref. 13)			X	X		
ERIM (ref. 5)		X	X	X		
LACIE field measurement data (ref. 14)		X		X		
North Dakota crop and livestock statistics (refs. 6, 8, and 15 to 18)	X		X			X

[a]Barley is generally planted after wheat.

[b]Barley tends to green up sooner than spring wheat and to obtain higher levels.

[c]Barley turns and matures earlier than wheat.

[d]Barley tends to be brighter than wheat after heading.

[e]Rye is greener than wheat. (Rye, a winter grain, was not considered in the spring wheat study.)

[f]Oats are not as green as wheat and may mature earlier than wheat. (Data on oats were limited.)

6. DIRECT WHEAT PROCEDURE

6.1 INTRODUCTION

The procedure recommendations and comments stated herein for a direct wheat procedure do not represent the final solution to the wheat estimation problem. They are representative of the data available to the analyst and are compatible with the current segment classification procedure (Procedure 1).

The procedure recommendations result from detailed analyses of the following:

1. Small-grain signatures on PFC Product 1
2. Small-grain signatures on PFC Product 3
3. Scatter plots (green number versus brightness)
4. Time plots (green number and brightness)
5. Crop calendar plots (green number and brightness versus Robertson scale adjustable and nominal crop calendars)
6. Means and standard deviation for small-grain dots
7. Channel plots (radiance values)

6.2 RECOMMENDED DIRECT WHEAT PROCEDURE

The steps in the direct barley procedure are as follows:

1. Classify by machine and obtain a BCE of small grains using Procedure 1. If possible, select a mid-heading to mid-ripe acquisition as the base acquisition.
2. If there are not any acquisitions covering the mid-heading to mid-ripe development stages, pass a total small-grain estimate. If the necessary acquisitions are available, proceed to step 3.

3. Consult the historical statistics in conjunction with full-frame coverage. Decide the importan e of the various small grains in the county and relate that information to the segment.

4. Check the crop calendar data, separation guidelines, green number growth patterns, and brightness patterns for the CRD in which the segment is located.

5. Study the scatter plots for the mid-heading to mid-ripe acquisitions. Choose the acquisition that seems to show the most separability. Draw a decision line (as shown in fig. 21) separating wheat and oats from barley.

6. Locate on the scatter plot each pixel classified S. Beside each S-classified pixel on a listing of dot classification ordered by dot number (table 4), place a B (barley) or OSG (other small grains) label.

7. Omit those S pixels that are determined to be nonsmall grains.

8. Tally the number of S pixels in the two grain classes (B and OSG).

9. Determine the proportion of pixels given separation labels for the barley class.

$$\frac{\text{Number of B pixels}}{\text{Total number of pixels labeled B or OSG}}$$

10. Determine the percentage of barley for the segment.

P_B = Proportion of barley

SG_{BCE} = BCE for small grains

11. Subtract the percentage of barley from the BCE to obtain the percentage of other small grains in the segment.

It would be necessary for CAS to ratio the oats from the OSG estimate.

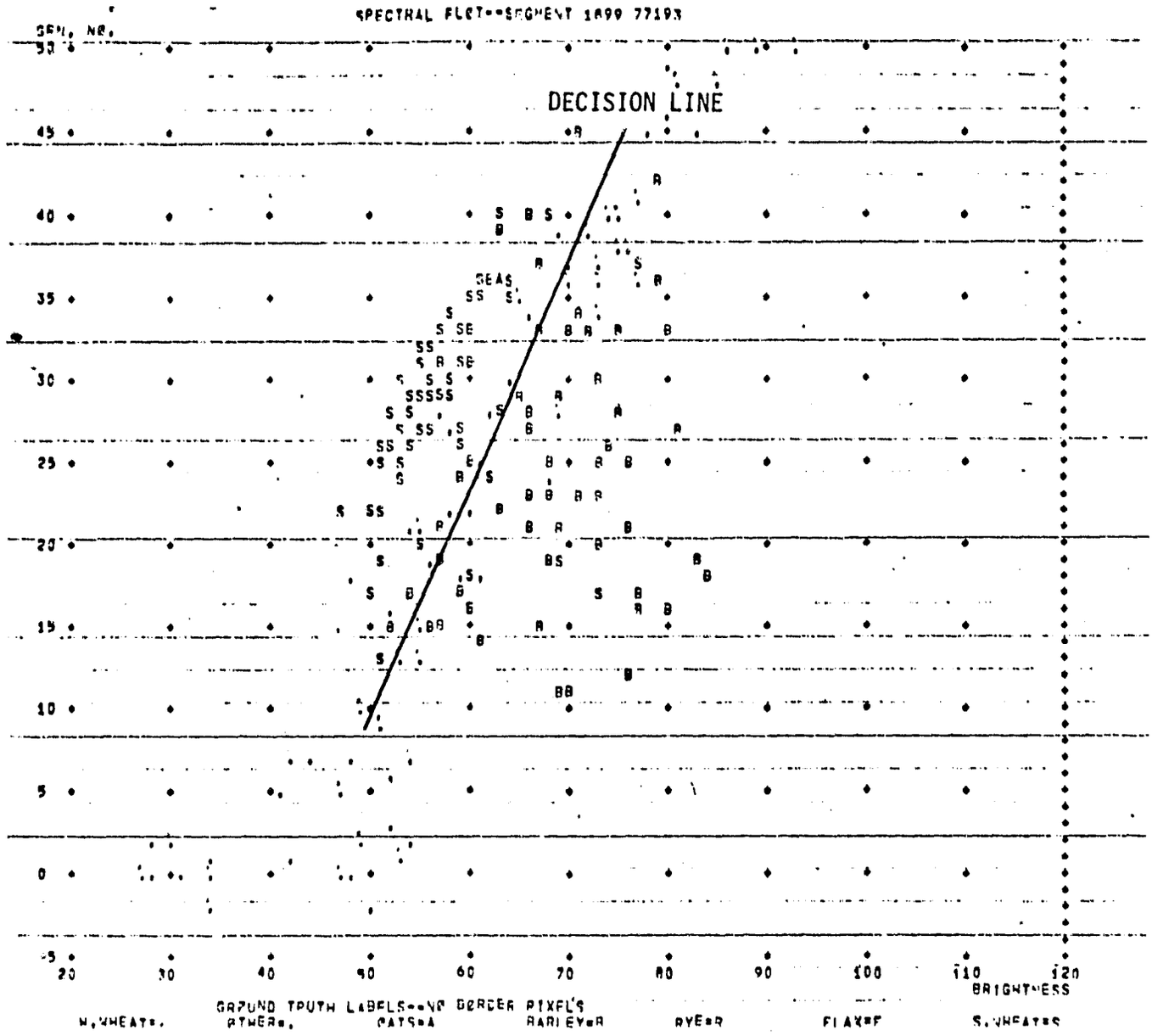


Figure 21.— Scatter plot for segment 1899 (acquisition date, 77193) — green number versus brightness illustrating decision line for direct barley.

6.3 PROCEDURAL PROBLEMS

Six problems are inherent with the direct barley procedure.

- Separation of small grains appears to be possible only during the mid-heading to mid-ripe stages. If acquisitions covering these development stages are missing, separation is not probable.
- Oats are not separable from wheat in the available data set, thus indicating a continuing requirement for ratioing.
- Wheat/barley separation is not always immediately obvious.
- Low-density segments present a separability problem because of the low population of small-grain dots.
- Border and edge pixels of small-grain fields do not represent "true" grain signatures. These are shaky pixels upon which to base separation decisions.
- Specific parameters of green numbers and brightness values were not established because of segment-to-segment variability as well as crop development variability within the segment.

6.4 RECOMMENDATIONS TO IMPROVE SEPARATION TECHNIQUES

The following recommendations to improve separation techniques are offered:

1. During the jointing, heading, soft dough, and ripe stages, 9-day coverage would be desirable for obtaining the best possible separation date. The scatter plots for segment 1663 illustrate the need for 9-day coverage. The acquisition dates 7174-7175 are too early for good separation of barley from other spring small grains, and the acquisition date 7193 seems to be a little late. It is probable that coverage for 7183-7184 would have shown the best separability.
2. Omitting border and edge pixels from the separation may improve the probability of obtaining estimates of barley and other small grains. This approach should be examined more closely.

3. Green number growth patterns and brightness plots by CRD for small grains would illustrate the in-state variability. These should be adjustable according to planting and emergence dates.

4. The adjustable crop calendar for barley (still in the development stage) would assist the analyst in choosing a separation date. One could compare the barley calendar to the adjustable spring wheat crop calendar and "know" when barley development moves ahead of spring wheat development.

5. Historical acreage statistics for small grains and other major crops are necessary ancillary data for the analyst (as discussed in section 3.1.5).

These statistics should be used with the full-frame data in ascertaining the importance of specific crops in the segment as related to the county as a unit.

7. SUMMARY

The green number and brightness scatter plots, channel plots of radiance values, and visual study of the imagery indicate separability between barley and spring wheat/oats during the wheat mid-heading to mid-ripe stages. In the LACIE Phase III North Dakota data set, the separation time is more specifically the wheat soft dough stage. At this time, the barley is ripening — and therefore is less green and brighter than the wheat. Only 4 of the 18 segments studied indicate separation of barley/other spring small grain, even though 11 of the segments have acquisitions covering the wheat soft dough stage. The remaining seven segments had less than 5 percent barley based on ground-truth data.

Listed below are areas which require more investigation.

1. Segments with a low density of small grains and a low percentage of barley present a separation problem.
2. The border/edge pixel problem in relation to separation should be studied.
3. The channel plots of radiance values warrant further study. Segment 1899, acquisition 7193, indicates separation. Perhaps some type of data rotation or transformation could enhance this separation.

8. REFERENCES

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APPENDIX A

JULIAN DATE CALENDAR

APPENDIX A

JULIAN DATE CALENDAR

The Julian date calendar (perpetual and for leap years only) is presented on the following pages.

Day	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Day
1	001	032	060	091	121	152	182	213	244	274	305	335	1
2	002	033	061	092	122	153	183	214	245	275	306	336	2
3	003	034	062	093	123	154	184	215	246	276	307	337	3
4	004	035	063	094	124	155	185	216	247	277	308	338	4
5	005	036	064	095	125	156	186	217	248	278	309	339	5
6	006	037	065	096	126	157	187	218	249	279	310	340	6
7	007	038	066	097	127	158	188	219	250	280	311	341	7
8	008	039	067	098	128	159	189	220	251	281	312	342	8
9	009	040	068	099	129	160	190	221	252	282	313	343	9
10	010	041	069	100	130	161	191	222	253	283	314	344	10
11	011	042	070	101	131	162	192	223	254	284	315	345	11
12	012	043	071	102	132	163	193	224	255	285	316	346	12
13	013	044	072	103	133	164	194	225	256	286	317	347	13
14	014	045	073	104	134	165	195	226	257	287	318	348	14
15	015	046	074	105	135	166	196	227	258	288	319	349	15
16	016	047	075	106	136	167	197	228	259	289	320	350	16
17	017	048	076	107	137	168	198	229	260	290	321	351	17
18	018	049	077	108	138	169	199	230	261	291	322	352	18
19	019	050	078	109	139	170	200	231	262	292	323	353	19
20	020	051	079	110	140	171	201	232	263	293	324	354	20
21	021	052	080	111	141	172	202	233	264	294	325	355	21
22	022	053	081	112	142	173	203	234	265	295	326	356	22
23	023	054	082	113	143	174	204	235	266	296	327	357	23
24	024	055	083	114	144	175	205	236	267	297	328	358	24
25	025	056	084	115	145	176	206	237	268	298	329	359	25
26	026	057	085	116	146	177	207	238	269	299	330	360	26
27	027	058	086	117	147	178	208	239	270	300	331	361	27
28	028	059	087	118	148	179	209	240	271	301	332	362	28
29	029		088	119	149	180	210	241	272	302	333	363	29
30	030		089	120	150	181	211	242	273	303	334	364	30
31	031		090		151		212	243		304		365	31

(a) Perpetual.

Figure A-1.— Julian date calendar.

Day	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Day
1	001	032	061	092	122	153	183	214	245	275	306	336	1
2	002	033	062	093	123	154	184	215	246	276	307	337	2
3	003	034	063	094	124	155	185	216	247	277	308	338	3
4	004	035	064	095	125	156	186	217	248	278	309	339	4
5	005	036	065	096	126	157	187	218	249	279	310	340	5
6	006	037	066	097	127	158	188	219	250	280	311	341	6
7	007	038	067	098	128	159	189	220	251	281	312	342	7
8	008	039	068	099	129	160	190	221	252	282	313	343	8
9	009	040	069	100	130	161	191	222	253	283	314	344	9
10	010	041	070	101	131	162	192	223	254	284	315	345	10
11	011	042	071	102	132	163	193	224	255	285	316	346	11
12	012	043	072	103	133	164	194	225	256	286	317	347	12
13	013	044	073	104	134	165	195	226	257	287	318	348	13
14	014	045	074	105	135	166	196	227	258	288	319	349	14
15	015	046	075	106	136	167	197	228	259	289	320	350	15
16	016	047	076	107	137	168	198	229	260	290	321	351	16
17	017	048	077	108	138	169	199	230	261	291	322	352	17
18	018	049	078	109	139	170	200	231	262	292	323	353	18
19	019	050	079	110	140	171	201	232	263	293	324	354	19
20	020	051	080	111	141	172	202	233	264	294	325	355	20
21	021	052	081	112	142	173	203	234	265	295	326	356	21
22	022	053	082	113	143	174	204	235	266	296	327	357	22
23	023	054	083	114	144	175	205	236	267	297	328	358	23
24	024	055	084	115	145	176	206	237	268	298	329	359	24
25	025	056	085	116	146	177	207	238	269	299	330	360	25
26	026	057	086	117	147	178	208	239	270	300	331	361	26
27	027	058	087	118	148	179	209	240	271	301	332	362	27
28	028	059	088	119	149	180	210	241	272	302	333	363	28
29	029	060	089	120	150	181	211	242	273	303	334	364	29
30	030		090	121	151	182	212	243	274	304	335	365	30
31	031		091		152		213	244		305		366	31

(USE IN 1964, 1968, 1972, etc.)

(b) For leap years only.

Figure A-1.— Concluded.

APPENDIX B

ERROR CHARACTERIZATION FOR PHASE III NORTH DAKOTA BLIND SITES

By J. M. Clinton

APPENDIX B

ERROR CHARACTERIZATION FOR PHASE III NORTH DAKOTA BLIND SITES

By J. M. Clinton

The type of errors that characterized the 18 blind sites in North Dakota during Phase III are presented in tables A-1 to A-5.

The confusion matrices for these errors are as follows.

% correctly labeled	% omission error
$\frac{\text{total correctly labeled small grain}}{\text{total small grain labeled}}$	$\frac{\text{total small grain error}}{\text{total small grain labeled}}$
$\frac{\text{total nonsmall grain error}}{\text{total nonsmall grain labeled}}$	$\frac{\text{total correctly labeled nonsmall grain}}{\text{total nonsmall grain labeled}}$
% commission error	% correctly labeled

Performance Analysis* Ground Truth

Type 2		Type 1	
$\frac{341}{455} = 0.750$	$\frac{114}{455} = 0.250$	$\frac{231}{310} = 0.745$	$\frac{79}{310} = 0.255$
$\frac{30}{563} = 0.053$	$\frac{533}{563} = 0.947$	$\frac{22}{375} = 0.059$	$\frac{353}{375} = 0.941$

*"Performance Analysis" refers to the title of an administration section of personnel.

AA Tape Ground Truth

Type 2		Type 1	
$\frac{308}{455} = 0.677$	$\frac{147}{455} = 0.323$	$\frac{200}{310} = 0.645$	$\frac{110}{310} = 0.355$
$\frac{59}{563} = 0.105$	$\frac{504}{563} = 0.895$	$\frac{33}{375} = 0.088$	$\frac{342}{375} = 0.912$

Total small grains labeled: 455, type 2; 310, type 1
Total nonsmall grains labeled: 563, type 2; 375, type 1

TABLE B-1.— CAUSES FOR OMISSION AND COMMISSION ERRORS IN LABELING TYPE 1 AND TYPE 2 DOTS

Error cause	Omission, %		Commission, %	
	Type 1	Type 2	Type 1	Type 2
Insufficient acquisitions	20.3	13.2	40.9	33.3
Fields too narrow	7.6	11.4	—	3.3
Border/edge	7.6	28.9	18.2	23.3
Abnormal signature	15.2	21.1	13.6	16.7
Total error	50.7	74.6	72.7	76.6
Poor stand	3.8			
Late planting and development	18.9	10.5		
Early planting and development	5.1	7.9		
Wrong acquisition used for base	1.3			
Inadvertent error	11.4	5.3	18.2	16.7
Unlike other causes	7.6	1.8	9.1	6.7
Small grains confused with nonsmall grains	1.3			

TABLE B-2.-- SEGMENTS WITH INADEQUATE ACQUISITIONS

Segment	Error		Missing growth stages*
	Type 1	Type 2	
1604	12	16	b, e
1635	1	3	b, c, f, g
1648	7	4	a, b
1661	1	4	b, c

*Codes for growth stages are as follows:
a = Planting through emergence
b = Postplanting, postemergence
c = Postemergence, tillering
e = Tillering through heading
f = Turning, ripen
g = Harvest

TABLE B-3.— LOW-ERROR SEGMENTS

Segment	Error		Growth stages present*
	Type 1	Type 2	
1622	1	5	a, b, e
1637	3	5	a, b, e
1640	0	4	a, c, e
1663	1	4	a, b, e
1903	0	0	b, e
1927	3	1	b, c, e

*Codes for crop growth stages are as follows:
a = Planting through emergence
b = Postplanting, postemergence
c = Postemergence, tillering
e = Tillering through heading
f = Turning, ripen
g = Harvest

TABLE B-4.— GENERALIZED DESCRIPTION OF ERRORS

Parameter	Percentage	
	Type 1	Type 2
Labeled pixels in strip/fallow[a]	3.2	4.2
Strip/fallow fields with integrated signatures	1.5	1.6
Pixels in integrated strip/fallow fields labeled other	0.7	0.8
Error of all pixels labeled	14.7	14.1
All labeled pixels misregistered in AA tape ground truth	9.1	11.7
All labeled pixels mislabeled on AA ground-truth overlay	0.7	1.0
All labeled pixels that are border/edge	5.4	11.8

[a]The number of segments affected is four.

TABLE B-5.— EXPLANATION OF COMMISSION ERRORS AND IDLE CROPLAND/FALLOW ERRORS

Parameter	Percentage	
	Type 1	Type 2
All labeled commission errors as to crop identification:		
Idle cropland/fallow.	9.1	33.3
Flax. . . . . [a].	5.0	7.0
All other crops, each[a].	5.0	3.3
Cause of error for all idle cropland/fallow:		
Border/edge	50.0	40.0
Inconsistency (analyst labeling). .	50.0	30.0
Inadequate acquisitions	—	20.0
Abnormal signatures	—	10.0

[a]Pasture, grass, hay, millet, sunflowers, homestead, alfalfa, spring wheat/strip fallow, sugar beets.

[b]Sample population of 10 pixels.

APPENDIX C

HISTORICAL ACREAGE STATISTICS ON NORTH DAKOTA'S 18 BLIND SITES, BY YEAR

APPENDIX C

HISTORICAL ACREAGE STATISTICS ON NORTH DAKOTA'S 18 BLIND SITES, BY YEAR

Specific crop acreages for the 18 blind sites during the 5-year period from 1972 to 1976 are given in this appendix for small grains as a whole, all wheat, spring wheat, durum, barley, and oats. See table C-1, (a) to (f).

TABLE C-1.— HISTORICAL ACREAGE STATISTICS ON NORTH DAKOTA'S 18 BLIND SITES, BY YEAR

(a) Small grains.

County	1972		1973		1974		1975		1976	
	Planted	Harvested	Planted	Harvested	Planted	Harvested	Planted	Harvested	Planted	Harvested
Barnes	417 500	409 200	448 300	431 800	467 000	461 600	446 700	432 800	494 700	488 900
Bowman	145 400	139 500	151 700	145 200	166 900	160 500	155 100	144 700	167 600	156 000
Cavalier	415 000	408 200	492 500	470 000	483 000	461 900	491 000	485 100	501 700	484 700
Dunn	154 600	149 000	171 500	156 000	178 100	159 000	173 100	157 000	175 300	166 700
Grand Forks	373 000	367 800	412 500	405 000	429 800	421 300	470 000	463 900	510 800	504 800
Hettinger	238 900	232 800	259 200	253 000	279 100	273 400	268 600	250 500	286 000	281 100
McIntosh	148 000	144 400	164 400	148 900	194 600	183 400	188 000	185 300	216 800	205 300
Mercer	121 700	117 200	134 500	124 000	135 200	121 900	128 300	124 300	122 000	119 700
Mountrail	277 700	265 100	312 500	304 000	310 000	301 200	289 000	271 500	310 700	306 100
Ramsey	346 500	337 500	374 500	367 500	342 300	329 300	387 800	381 700	420 300	404 300
Renville	227 500	221 500	248 700	244 700	237 900	231 500	227 000	222 000	256 900	252 100
Richland	259 300	252 300	332 500	328 400	357 500	353 900	349 500	287 700	412 200	404 000
Sargent	140 000	137 900	181 500	176 500	183 400	179 200	181 700	165 400	207 300	203 000
Sheridan	166 100	160 500	184 000	171 500	188 100	179 100	195 200	190 500	216 800	209 000
Stark	208 400	198 900	230 600	218 800	238 200	224 600	234 700	226 900	249 800	240 100
Stutsman	490 800	479 200	515 500	493 500	559 700	541 700	537 500	523 800	563 200	552 000
Walsh	380 500	374 500	426 800	414 200	418 900	407 900	472 300	446 200	481 400	473 200
Ward	424 200	412 200	490 700	476 100	482 100	468 000	465 000	448 500	525 200	517 800

TABLE C-1.— Continued.

(b) All wheat.

County	1972		1973		1974		1975		1976	
	Planted	Harvested	Planted	Harvested	Planted	Harvested	Planted	Harvested	Planted	Harvested
Barnes	199 000	197 200	252 300	248 800	308 500	306 000	303 600	293 400	349 900	346 200
Bowman	83 400	80 000	83 200	80 200	124 500	121 700	118 200	111 300	138 800	130 400
Cavalier	245 000	242 700	307 000	297 000	318 200	307 700	315 500	312 000	321 500	310 300
Dunn	89 100	88 000	101 000	96 500	116 600	115 200	117 100	110 000	129 100	125 500
Grand Forks	213 000	211 800	253 000	250 000	290 300	286 100	306 300	302 000	335 100	331 300
Hettinger	161 400	159 300	154 700	153 500	227 700	225 400	234 600	220 300	250 200	248 700
McIntosh	83 000	81 900	102 900	98 900	134 900	132 900	144 400	143 500	175 400	168 500
Mercer	75 700	74 700	87 000	85 000	95 400	92 600	91 700	90 900	95 700	95 100
Mountrail	204 200	198 100	252 000	248 000	280 000	276 700	261 900	246 800	283 400	281 100
Ramsey	210 000	205 500	210 000	207 000	238 100	234 700	285 100	280 600	312 900	301 100
Renville	146 000	144 000	179 200	176 700	185 600	182 500	189 100	185 800	215 700	212 700
Richland	124 300	122 300	181 500	180 400	238 300	236 000	233 200	193 800	285 400	280 600
Sargent	60 000	58 900	93 500	92 000	111 700	110 200	114 000	104 600	139 500	137 600
Sheridan	112 100	111 000	130 000	126 500	140 100	138 000	150 210	149 000	174 200	169 800
Stark	126 400	123 900	142 600	139 800	170 200	166 300	178 500	174 700	194 700	192 200
Stutsman	298 300	293 200	347 000	339 500	426 200	417 200	422 400	411 300	457 100	452 500
Walsh	223 000	221 500	265 300	260 200	294 100	288 700	315 300	295 200	342 800	338 500
Ward	295 200	292 200	379 200	375 100	404 100	397 700	392 200	380 700	457 300	451 300

TABLE C-1.— Continued.

(c) Spring wheat.

County	1972		1973		1974		1975		1976	
	Planted	Harvested	Planted	Harvested	Planted	Harvested	Planted	Harvested	Planted	Harvested
Barnes	176 000	175 000	236 000	233 500	252 200	250 500	242 400	234 000	290 800	289 200
Bowman	59 000	57 000	58 000	57 000	86 700	85 500	70 800	70 400	97 500	91 400
Cavalier	117 000	116 000	17 900	173 000	167 200	161 400	126 800	125 900	142 600	137 200
Dunn	88 000	87 000	99 000	95 000	114 200	112 800	111 900	105 100	126 000	122 500
Grand Forks	200 000	199 000	237 000	235 000	26 200	258 700	266 500	263 100	301 700	298 600
Hettinger	154 000	152 000	146 000	145 000	209 400	207 600	210 800	198 100	224 000	222 800
McIntosh	72 000	71 000	92 000	89 000	110 300	109 000	112 200	111 500	142 600	136 400
Mercer	74 000	73 000	84 000	82 000	93 900	91 100	86 200	85 700	93 700	93 200
Mountrail	70 000	68 000	61 000	60 000	55 200	54 700	36 900	35 300	69 500	68 300
Ramsey	44 000	43 500	59 000	58 500	54 000	53 200	50 900	50 200	82 500	79 200
Renville	87 000	86 000	102 000	101 000	99 400	98 600	87 800	87 200	118 500	116 500
Richland	121 000	119 000	178 000	177 000	226 900	225 000	213 800	177 400	267 400	262 800
Sargent	52 000	51 000	82 000	81 000	86 900	86 100	76 700	71 600	101 700	101 200
Sheridan	103 000	102 000	115 000	112 000	120 200	118 400	131 300	130 500	156 500	152 200
Stark	118 000	116 000	135 000	133 000	166 000	162 400	150 000	149 000	168 200	166 400
Stutsman	186 000	185 000	262 000	256 000	292 400	289 000	275 400	266 700	335 100	332 700
Walsh	173 000	172 000	213 000	209 000	212 200	207 900	209 600	192 700	255 600	252 200
Ward	130 000	129 000	164 000	163 000	147 300	144 800	113 900	112 500	185 100	183 700

TABLE C-1.— Continued.

(d) Durum.

County	1972		1973		1974		1975		1976	
	Planted	Harvested	Planted	Harvested	Planted	Harvested	Planted	Harvested	Planted	Harvested
Barnes	23 000	22 200	16 000	15 500	55 600	54 900	59 200	57 500	56 100	54 400
Bowman	5 500	5 200	10 500	10 000	19 800	19 500	25 300	25 200	21 000	19 000
Cavalier	128 000	126 700	128 000	124 000	151 000	146 300	188 400	185 800	178 200	172 400
Dunn	10 500	10 500	2 000	1 500	2 400	2 400	4 600	4 500	2 800	2 800
Grand Forks	13 000	12 800	16 000	15 000	28 300	27 400	39 800	38 900	33 300	32 600
Hettinger	5 500	5 500	7 000	7 000	15 300	15 100	21 400	20 600	20 600	20 500
McIntosh	11 000	10 900	10 500	9 500	246 000	23 900	32 200	32 000	32 600	31 900
Mercer	1 500	1 500	3 000	3 000	1 500	1 500	5 300	5 100	1 700	1 700
Mountrail	134 000	130 000	191 000	188 000	224 800	222 000	224 700	211 200	213 100	212 000
Ramsey	166 000	162 000	151 000	148 500	183 100	180 700	233 700	230 000	230 200	221 700
Renville	59 000	58 000	77 000	75 500	86 200	83 900	101 300	98 600	97 200	96 200
Richland	3 000	3 000	2 000	2 000	7 400	7 400	16 500	13 800	15 800	15 700
Sargent	8 000	7 900	11 500	11 000	23 800	23 400	36 600	32 400	36 000	34 700
Sheridan	9 000	8 900	15 000	14 500	19 900	19 600	18 900	18 500	17 700	17 600
Stark	4 000	4 000	3 000	2 500	5 200	5 100	17 100	17 000	17 900	17 300
Stutsman	112 000	108 000	85 000	83 500	133 700	128 100	146 400	144 100	121 200	119 100
Walsh	50 000	49 500	52 000	51 000	81 900	80 800	105 700	102 500	86 900	86 000
Ward	165 000	163 000	214 000	211 000	256 300	252 500	277 400	267 400	271 800	267 200

TABLE C-1.— Continued.

(e) Barley.

County	1972		1973		1974		1975		1976	
	Planted	Harvested	Planted	Harvested	Planted	Harvested	Planted	Harvested	Planted	Harvested
Barnes	147 500	144 000	136 000	132 000	118 600	117 400	113 300	111 200	112 200	111 200
Bowman	29 000	27 500	37 500	37 000	16 900	15 800	11 300	11 000	6 600	6 000
Cavalier	149 000	146 500	161 500	151 000	152 000	142 300	158 000	156 900	163 300	158 300
Dunn	20 500	20 000	24 500	23 500	11 700	9 700	9 100	8 100	7 800	7 600
Grand Forks	128 000	126 000	129 500	127 000	111 000	108 000	134 300	133 000	153 200	151 400
Hettinger	32 500	31 500	58 500	57 500	18 100	17 700	8 700	7 900	13 600	13 200
McIntosh	17 000	16 500	16 500	15 000	12 000	11 700	8 400	8 400	8 200	8 100
Mercer	9 000	8 500	11 500	11 000	7 000	6 300	6 100	6 100	3 600	3 600
Mountrail	28 500	26 000	20 500	20 000	9 000	8 700	5 600	5 100	6 700	6 700
Ramsey	122 500	118 000	148 500	146 500	96 000	86 600	94 000	92 900	102 000	98 000
Renville	49 500	48 500	40 500	40 000	34 900	34 000	21 200	20 100	22 000	21 600
Richland	56 000	53 000	72 000	71 000	75 900	75 600	84 200	69 500	89 900	87 600
Sargent	36 000	35 000	42 000	40 500	40 000	39 900	35 900	31 100	41 200	40 800
Sheridan	19 000	18 500	20 000	18 000	15 700	14 700	15 500	15 300	17 400	17 100
Stark	23 000	21 000	28 000	26 000	13 900	12 800	11 100	10 700	9 500	9 200
Stutsman	87 500	86 000	82 500	81 000	65 000	63 100	57 700	56 500	62 100	59 300
Walsh	132 500	129 000	135 500	131 000	103 000	98 600	131 600	127 000	119 600	116 500
Ward	56 000	55 000	40 500	40 000	30 500	29 300	29 000	27 600	29 400	29 300

TABLE C-1.— Concluded.

(f) Oats.

County	1972		1973		1974		1975		1976	
	Planted	Harvested	Planted	Harvested	Planted	Harvested	Planted	Harvested	Planted	Harvested
Barnes	71 000	68 000	60 000	51 000	39 900	38 200	29 800	28 200	32 600	31 500
Bowman	33 000	32 000	31 000	28 000	25 000	23 000	25 600	22 400	22 200	19 600
Cavalier	21 000	19 000	24 000	22 000	12 800	11 900	17 500	16 200	17 200	16 100
Dunn	45 000	41 000	46 000	36 000	49 800	34 100	46 900	38 900	38 400	33 600
Grand Forks	32 000	30 000	30 000	28 000	28 500	27 200	29 400	28 900	22 500	22 100
Hettinger	45 000	42 000	46 000	42 000	33 200	30 300	25 300	22 300	22 200	19 200
McIntosh	48 000	46 000	45 000	35 000	47 700	38 800	35 200	34 400	33 200	28 700
Mercer	37 000	34 000	36 000	28 000	32 800	23 000	30 500	27 300	22 700	21 000
Mountrail	45 000	41 000	40 000	36 000	21 000	15 800	21 500	19 600	20 600	18 300
Pamsey	14 000	14 000	16 000	14 000	8 200	8 000	8 700	8 200	5 400	5 200
Penville	32 000	29 000	29 000	28 000	17 400	15 000	16 700	16 100	19 200	17 800
Richland	79 000	77 000	79 000	77 000	43 300	42 300	32 100	24 400	36 900	35 800
Sargent	44 000	44 000	46 000	44 000	31 700	29 100	31 800	29 700	26 600	24 600
Sheridan	35 000	31 000	34 000	27 000	32 300	26 400	29 500	26 200	25 200	22 100
Stark	59 000	54 000	60 000	53 000	54 100	45 500	45 100	41 500	45 600	38 700
Stutsman	105 000	100 000	86 000	73 000	68 500	61 400	57 400	56 000	44 000	40 200
Walsh	25 000	24 000	26 000	23 000	21 800	20 600	25 400	24 000	19 000	18 200
Ward	73 000	65 000	71 000	61 000	47 500	41 000	43 800	40 200	38 500	37 200

APPENDIX D

ACQUISITION AND FIELD RECORD OF SPECTRAL SIGNATURES

APPENDIX D

ACQUISITION AND FIELD RECORD OF SPECTRAL SIGNATURES

Field signatures on specific acquisitions are described for the 18 blind sites: 1602, 1604, 1606, 1616, 1619, 1622, 1625, 1635, 1637, 1640, 1648, 1652, 1661, 1663, 1899, 1903, 1913, and 1927. The dates (Julian and calendar) and the field numbers for barley, oats, spring wheat, winter wheat, durum, and fallow (B, O, SW, WW, DU, and F, respectively), are given in the following forms.

Segment 1602

Date	Crop	Field	Comments
7125 (5/5/77)			Pre-emergence for small grains
7143 (5/21/77)	SW	258	Pink; partial emergence typical of spring wheat signature
	B	275	Same partial emergence as for SW258
	SW	407	Same as for SW258
	0	347	Pre-emergence; green signature
7179 (6/28/77)			Clouds and haze influenced signatures All spring grain signatures the same red
7198 (7/17/77)	SW	258	Bright red; typical spring grain signature
	B	275	Brighter red than for SW258
	B	161	Bright pink; unique signature
	SW	407	Same red as for SW258
	0	347	Red signature same as for SW258
	SW	235	Same as for 0347
			GENERAL: 1. Separation hindered by small amount of barley in segment 2. Oats' signature same as spring wheat's 3. Barley seemingly brighter and pinker than other spring small grains

Segment 1604

Date	Crop	Field	Comments
7125 (5/5/77)			Small grain fields still emerging; insufficient data available
7143 (5/23/77)			Small grain fields still emerging

Segment 1606

Date	Crop	Field	Comments
7125 (5/5/77)			Pre-emergence
7143 (5/23/77			Pre-emergence
7179 (6/28/77)			Clouds and haze
7197 (7/16/77)	SW	97	Bright red
	O	4	Bright red same as SW97
	B	198	Mottled green/gold/red
	B	280	Pink (different from all other small grain fields)
	B	102	Brownish red (turning) signature
	SW	60	Eastern portion of this field same as B102
	SW	301	Same as SW97
	O	211	Brownish green same as an unnumbered spring wheat field in northern part of segment
7250 (9/7/77)			Harvested
			GENERAL:
			1. Spring small grains not visually separable
			2. Wheat the same as some oats and other oat fields the same as barley

Segment 1616

Date	Crop	Field	Comments
7122/7123 (5/2,3/77)			Pre-emergence
7140 (5/20/77)			Clouds
7141 (5/21/77)			Partial emergence
7158 (6/7/77)			Consecutive-day coverage
7159 (6/8/77)	B	89	Bright red signature
	SW	28	Bright red signature
	SW	70	Bright red signature
	SW	21	Mottled gray signature; just emerging
	B	153	Mottled gray signature; just emerging
	B	108	Mottled red signature
	SW	49	Mottled red signature
7230 (8/18/77)			Harvested
			GENERAL: Wheat and barley unseparable

Segment 1619

Date	Crop	Field	Comments
7122 (5/2/77)			Pre-emergence
7140 (5/20/77)	SW	68	Red lavender emergence
	B	214	Red lavender emergence
	SW	302	Red lavender emergence
	B	202	Red lavender emergence
	SW	83	Redder signature than fields 68, 214, 302, and 202
	SW	*91	Bright red signature
	B	210	Bright red signature
	SW	307	Mottled red signature
	O	182	Light green; different from other emerged spring grains but similar to nonemerged small grain signatures
			GENERAL:
			1. Signature showing various stages of emergence
			2. No distinctive signature for any of the small grains
7158 (6/7/77)	SW	68	Bright red signature
	B	214	Bright red signature
	SW	307	Bright red signature
	O	182	Bright red signature
	SW	83	Red signature
	B	186	Red signature
	SW	36	Red signature
	SW	302	Red signature
	B	202	Red signature
	SW	91	Red signature
	B	210	Red signature

*Southwest

Segment 1619.– Concluded.

Date	Crop	Field	Comments
			GENERAL:
			1. All small grains emerged
			2. No distinction between spring wheat, barley, or oats
7175	SW	68	Bright red signature
	SW	83	Red signature
	SW	91	Red signature
	B	210	Red signature
	SW	307	Red signature
	SW	36	Bright red signature
	B	186	Bright red signature
	B	214	Darker red than field SW68
	SW	302	Red signature; beginning to turn
	B	202	Lighter red than field SW302
	O	182	Red signature but more lavender red than the majority of spring wheat fields
	SW	27	Red signature but more lavender red than the majority of spring wheat fields
			GENERAL:
			1. Spring wheat headed with some turning taking place
			2. All spring wheat signatures bright reds to red and yellow mottled signatures
			3. Barley and oat signatures very similar to spring wheat signatures
			4. No visual separation in small grains
7176			Clouds
7230			Harvested

Segment 1622

Date	Crop	Field	Comments
7122 (5/22/77)			Pre-emergence
7140/7141 (5/20,21/77)	B	88	Emerging signatures
	SW	21	Emerging signatures
	SW	300	Emerging signatures
	SW	301	Emerging signatures
7159 (6/8/77)	B	*88	Bright red
	SW	29	Bright red
	SW	308	Bright red
	SW	4	Bright red
	SW	310	Bright red
	B	106	Light red
	B	95	Light red
	B	101	Light red
	SW	312	Red
	SW	34	Red
	SW	37	Red
	SW	305	Red
	B	108	Not emerged
7176 (6/25/77)	SW	13	Red
	SW	14	Red
	SW	25	Red
	SW	**34	Red
	SW	308	Red
	B	88	Mottled reddish signatures
	B	108	Mottled reddish signatures
	SW	300	Mottled reddish signatures
	SW	301	Mottled reddish signatures
	B	106	Mottled reddish signatures

*Eastern
**West

Segment 1622.-- Concluded.

Date	Crop	Field	Comments
	B	105	Mottled reddish signatures
	SW	311	Mottled reddish signatures
	O	171	Mottled reddish signatures
	O	174	Beginning to emerge
	SW	30	Emerging
7230 (8/18/77)			Harvest
			GENERAL: No visual separation between the grains

Segment 1625

Date	Crop	Field	Comments
7125 (5/5/77)			Pre-emergence
7143 (5/23/77)			Haze influenced
	O	277	Light red, almost light brown, similar to SW303
	SW	303	Light red mixed with light brown
	SW	312	Light green, much of other spring wheat similar to this signature
	B	92	Mottled red and brighter browns
7179 (6/28/77)			
	O	277	Light red to light brown similar to SW216
	SW	303	Bright red; major spring wheat signature at this date
	SW	305	Bright red; major spring wheat signature at this date
	SW	312	Mottled red not as solid as SW303
	SW	312	Mottled red not as solid as SW303
	B	92	Brighter light red than other spring grains but similar to some spring grain strip fields
7197 (7/16/77)			Cloud covered
7233 (8/21/77)			Small grains showing harvest
			GENERAL:
			1. Small amount of spring grains in segment
			2. Date 7179 only possible separation date a. Barley brighter than spring wheat b. Oats similar to some spring wheat
			3. Separation made difficult by strip fields

Segment 1635

Date	Crop	Field	Comments
7105 (4/15/77)			Pre-emergence
7123 (5/3/77)			Pre-emergence
7159 (6/8/77)	SW	141	Strongest field with major red signature for spring wheat GENERAL: 1. Almost no spring grains other than spring wheat 2. Spring grains small strips 3. All spring grains the same red signature

Segment 1637

Date	Crop	Field	Comments
7123 (5/3/77)			Pre-emergence
7140 (5/20/77)	B	185	Barley fields emerging; same light red signature as emerging spring wheat fields and early-planted oat fields
	SW	*15	Barley fields emerging; same light red signature as emerging spring wheat fields and early-planted oat fields
	B	174	Barley fields emerging; same light red signature as emerging spring wheat fields and early-planted oat fields
	O	196	Barley fields emerging; same light red signature as emerging spring wheat fields and early-planted oat fields
7159 (6/8/77)	B	185	Cloud coverage on 40 percent of segment
	DU	80	Bright red signature
	SW	15	Bright red signature
	B	174	Bright red signature
	SW	31	Bright red signature
	SW	26	Dull red signature
	SW	4	Dull red signature
	B	180	Dull red signature
	B	175	Dull red signature
7194 (7/13/77)			Clouds and haze; signatures not distinctive
7248 (9/5/77)			Harvested
			GENERAL:
			1. Interpretation hindered by clouds and haze
*Northern			2. Spring grains not visually separable

Segment 1640

Date	Crop	Field	Comments
7121/7122 (5/1,2/77)			Pre-emergence
7139 (5/19/77)			Haze
7140 (5/20/77)	B	163	Pinkish red
	B	93	Pinkish red
	B	452	Pinkish red
	SW	427	Pinkish red
	SW	301	Lavender signature, emerging fields
	B	137	Lavender signature, emerging fields
	O	12	Lavender signature, emerging fields
	B	206	Green, not emerged
	SW	199	Green, not emerged
7175 (6/24/77)	B	137	Bright red signature
	SW	311	Bright red signature
	O	12	Bright red signature
	SW	306	Red signature
	B	8	Red signature
	B	208	Red signature
	SW	302	Red signature
	SW	180	Mottled brown and red; probably a poor stand
	B	137	Mottled pink and gold signature
7193 (7/12/77)	B	208	Harvested
	SW	311	Bright red signature
	SW	302	Bright red signature
	O	12	Bright red signature
	B	341	Bright red signature

Segment 1640.– Concluded.

Date	Crop	Field	Comments
	B	299	Ripe signature
	SW	306	Dull red signature
	SW	336	Dull red signature
	O	397	Dull red signature
	B	432	Dull red signature
7194 (7/13/77)			Clouds and haze
7211 (7/30/77)	B	137	Harvested
	O	12	Harvested
	B	478	Harvested
	O	95	Harvested
	SW	375	Ripe
	SW	306	Ripe
	SW	86	Ripe
	B	486	Ripe
7229 (8/17/77)			Harvested
			GENERAL:
			1. 7211 – most probable date for possible separation
			2. 7211 – date that most barley and some oat fields are harvested

Segment 1648

Date	Crop	Field	Comments
7107 (4/17/77)			Pre-emergence for spring wheat; winter wheat not separable from fields destined to be spring wheat
7125 (5/5/77)			Pre-emergence for spring wheat; winter wheat signatures green to pink
7143 (5/23/77)			Haze and data dropout
7179 (6/28/77)			Small grain fields; red signature to an integrated red signature (field boundaries not apparent) GENERAL: 1. Nearly all small grains in strip fallow fields 2. No visual separation apparent between winter wheat, spring wheat, barley, and oats 3. Problems identifying small grains because of narrow strip fields

Segment 1652

Date	Crop	Field	Comments
7125 (5/5/77)			Pre-emergence
7143 (5/23/77)			Pre-emergence
7179 (6/27/77)	SW	81	Bright red signature
	SW	83	Bright red signature
	B	148	Strip fields; pink signature
	SW	314	Strip fields; pink signature
	SW/F	222	Mottled signature; integrated fields – field boundaries not discernible
	SW/F/ O/C	215	Mottled signature; integrated fields – field boundaries not discernible
	SW	310	Dull red signature
7197 (7/16/77)	SW	310	Mottled red/green-gold signature
	SW/F	79	Mottled green/gold signature
	SW/F	222	Green signature
	SW/F/ O/C	215	Green signature
	SW	81	Bright red signature
	SW	83	Dull red signature
	WW	308	Harvested
	WW	309	Harvested
7233 (8/21/77)			Harvested
			GENERAL:
			1. Very little barley
			2. Strip/fallow fields
			3. No separation

Segment 1661

Date	Crop	Field	Comments
7123 (5/3/77)			Pre-emergence
7159 (6/8/77)	B	134	Same red signature as SW40 but not as bright as SW135
	SW	40	Red signature
	SW	135	Bright red signature typical of spring wheat
	SW	307	Bright red signature typical of spring wheat
	246	0	Same red as SW307
			GENERAL:
			1. Small amount of spring grain other than spring wheat
			2. Identification of spring grains difficult because of strip fields
			3. No visual separation

Segment 1663

Date	Crop	Field	Comments
7120 (4/30/77)			Pre-emergence
7121 (5/1/77)			Pre-emergence
	SW	59	
7138 (5/18/77)	SW	22	Bright red; fully emerged
	B	142	Bright red; fully emerged
	B	140	Bright red; fully emerged
	SW	13	Dark red
	B	141	Brighter red than other signatures
	SW	300	Mottled green
	O	194	Mottled green
	B	129	Mottled green
7139 (5/19/77)			Haze over segment
7156 (6/5/77)	SW	22	Solid dark red
	SW	13	Solid dark red
	B	142	Solid dark red
	O	194	Solid dark red
	SW	300	Solid dark red
	SW	59	Solid dark red
	O	207	Solid dark red
	B	158	Solid dark red
	B	141	Brightest red signature
	B	140	Bright red
	B	129	Bright red
7157 (6/6/77)			No change from 7156

Segment 1663.— Continued.

Date	Crop	Field	Comments
7174 (6/23/77)	SW	22	Mottled red
	SW	13	Mottled red; brown turning signature
	B	142	Mottled red; brown turning signature
	B	140	Mottled red; brown turning signature
	B	141	Light red/yellow
	O	194	Solid red
	B	129	Solid red
	SW	53	Solid red
	SW	300	Dark red
	O	207	Dark red
	SW	59	Dark red
	B	158	Light green; ripe or harvest
7175 (6/24/77)			No change from 7174
7193 (7/12/77)	B	142	Green; mature or harvest
	SW	22	Green; mature or harvest
	B	141	Green; mature or harvest
	O	207	Green; mature or harvest
	SW	13	Red/yellow; mature
	B	129	Dark green; plowed
	B	158	Dark green; plowed
	SW	300	Dark brown; ripe
	O	207	Dark brown; ripe
7211 (7/30/77)	SW	22	Dark green; plowed
	SW	13	Dark green; plowed
	B	142	Dark green; plowed
	O	194	Bright light green; harvest

Segment 1663.-- Concluded.

Date	Crop	Field	Comments
	B	129	Bright light green; harvest
	B	123	Bright light green; harvest
7229 (8/17/77)			Spring grain harvested
			GENERAL:
			1. Tendency for barley to be brighter on date 7156
			2. Some barley same all through
			3. No oats separation
			4. Possible separation 7156

Segment 1899

Date	Crop	Field	Comments
7122 (5/2/77)			Pre-emergence
7140 (5/20/77)	B	129	Emerging pink/lavender signature
	SW	306	Emerging pink/lavender signature
	B	276	Emerging pink/lavender signature
	SW	275	Emerging pink/lavender signature
7157 (6/6/77)	B	276	Bright red signature
	B	261	Bright red signature
	B	285	Dull red
	SW	306	Dull red
	SW	275	Dull red
	SW	301	Red signature
	B	6	Red signature
	B	129	Red signature
	SW	175	Red signature
	SW	307	Mottled lavender
	B	61	Mottled lavender
	B	79	Red signature
7175 (6/24/77)	SW	32	Mottled red, orange, brownish red
	B	28	Mottled red, orange, brownish red
	SW	306	Mottled red, orange, brownish red
	B	61	Mottled red, orange, brownish red
	SW	307	Mottled red, orange, brownish red
	SW	275	Mottled red, orange, brownish red
	B	279	Mottled red, orange, brownish red
	B	272	Slightly brighter than B279
			GENERAL: little visual difference in small-grain signatures on this acquisition

Segment 1899.— Concluded.

Date	Crop	Field	Comments
7193 (7/12/77)	SW	22	Dark red, brownish red
	SW	43	Dark red, brownish red
	SW	275	Dark red, brownish red
	SW	301	Dark red, brownish red
	B	6	Dark red, brownish red
	SW	307	Dull red
	SW	304	Dull red
	B	285	Ripe
	B	2	Ripe
	B	319	Ripe
	SW	314	Nearly ripe
			GENERAL:
			1. 7193 best date for separation
			2. Good field sizes in segment

Segment 1903

Date	Crop	Field	Comments
7125 (5/5/77)			Pre-emergence
7179 (6/28/77)	SW	28	Bright red typical spring grain signature
	SW	73	Bright red typical spring grain signature
	SW	104	Bright red typical spring grain signature
	SW	49	Bright pink
	B	411	Bright red same as SW73
	O	208	Red similar to SW104
7196 (7/15/77)			Cloud cover over 40 percent
7197 (7/16/77)	SW	28	Dark red turning signature
	SW	73	Dark red turning signature
	SW	104	Mottled red/brown
	SW	49	Mottled red/brown
	B	411	Bright pink; small amount on segment
	O	208	Mottled red/brown similar to SW49 and SW104
	B	320	Dark red similar to SW28
7233 (8/21/77)			Spring grains harvested
			GENERAL:
			1. Very little barley
			2. Barley signatures similar to spring wheat

Segment 1913

Date	Crop	Field	Comments
7125 (5/5/77)			Pre-emergence
7143 (5/23/77)	SW	266	Lavender; partial emergence
	SW	159	Light brown
	0	158	Light brown; same as spring wheat
	SW	250	Green; pre-emergence
	0	251	Mottled red/lavender
7161 (6/10/77)	SW	266	Red mottled with lavender
	SW	159	Light red/brown
	0	158	Light red/brown
	SW	250	Red mottled with bright pixels
	WW	133	Bright red
	0	251	Bright red similar to WW133
	SW/F	47	Bright pink like SW42
7179 (6/28/77)	SW	266	Bright red typical of most small grains
	SW	250	Bright red typical of most small grains
	0	251	Bright red typical of most small grains
	WW	133	Bright red typical of most small grains
	0	158	Mottled red/brown
	SW	159	Light red
	B/F	263	Red; same as SW309
7197 (7/16/77)	SW	266	Dark red turning signature
	SW	159	Dark red turning signature
	SW	250	Dark red turning signature
	WW	133	Red/brown turning
	SW	162	Red/brown turning
	0	158	Red/brown turning
	0	251	Bright light green harvest signature
	SW	309	Bright red

Segment 1913.– Concluded.

Date	Crop	Field	Comments
	B/F	263	Bright red
7215 (8/3/77)	SW	266	Brown/yellow; ripe signature; ripe looking
	SW	159	Brown/yellow; ripe signature; ripe looking
	0	251	Brown/yellow; ripe signature; ripe looking
	SW	250	Brown/yellow; ripe signature; ripe looking
	0	158	Yellow, ripe to harvest; similar to SW78
	SW	133	Bright yellow; ripe signature
	B/F	263	Barley same as SW314 brown-yellow
7233 (8/21/77)			Cloud and haze cover
			GENERAL:
			1. Small amount of barley
			2. Oat fields the same as other spring grains throughout growing season
			3. No separation

Segment 1927

Date	Crop	Field	Comments
7121/7122 (5/1,2/77)			Pre-emergence
7140 (5/20/77)	SW	18	Red lavender signature
	SW	*103	Red lavender signature
	B	179	Red
	B	41	Bright red
	SW	72	Lavender
	B	26	Lavender
	SW	**82	Dark green; not emerged
	B	46	Dark green; not emerged
7157/7158 (6/6,7/77)	SW	72	Bright red
	B	26	Bright red
	B	32	Bright red
	B	38	Bright red
	O	148	Bright red
	SW	103	Red/pink red
	SW	***18	Red/pink red
	SW	82	Red/pink red
	B	27	Bright pink
7175/7176 (6/24,25/77)	B	32	Red signature
	O	29	Red signature
	B	27	Red signature
	B	26	Red signature
	SW	72	Red signature
	SW	103	Red signature
7193/7194 (7/12,13/77)	B	26	Green/brown
	SW	72	Green/brown
*Western **Eastern ***Southern	SW	18	Green; ripe

Segment 1927.– Concluded.

Date	Crop	Field	Comments
	O	114	Green/brown
	SW	301	Green/brown
	B	38	Green/brown
	SW	103	Mottled green/brown/red
	O	28	Dull red
	B	212	Harvested
	B	38	Harvested
	B	41	Harvested
7230 (8/18/77)			Harvest
			GENERAL: Most visual separation on 7193-7194 dates